

Locating RF Interference at HF

A proven and practical approach to dealing with RFI from grow lights and more.

Tom Thompson, WØIVJ

Radio frequency interference (RFI) increased dramatically in my neighborhood recently. Locating the sources was not easy, due in part to the distances involved. The typical range for a consumer device that meets the applicable FCC Part 15 or 18 emissions limits is usually no more than a few hundred feet. Some of the sources in my area, however, were more than a half-mile away. The usual “sniff” methods weren’t practical, and without an initial heading, the sources were difficult to find. Furthermore, they were primarily HF sources. I needed a radio direction finder, but an HF handheld Yagi was not an option!

Looking for Noise Sources

Some noise sources are caused by arcing power lines, which, at close range, can wipe out all bands from AM broadcast to beyond 70 centimeters. The noise is relatively constant and uniform across the spectrum. It sounds like a constant harsh raspy buzz everywhere you tune, and can often go away during periods of rain or high humidity.

Many power companies lack the resources to find and fix noise sources in a timely manner. Thus, hams can attempt to locate such sources as an aid to their power company. Finding a distant source can be difficult. Nearby, you can track power line noise at VHF or UHF right down to the pole. At

longer ranges, however, the noise might be heard only at HF. So, HF RDF to get you in VHF range can be a real time saver. See www.arrl.org/power-line-noise-faq for more information.

I also found that RFI from consumer devices can be problematic. While FCC Part 15 and Part 18 rules define emissions limits for most consumer electronics, the limits are high enough to allow interference to nearby radio receivers. FCC rules protect all licensed radio services from harmful interference, and the operator of an offending device must correct the problem. Therein lies the rub — someone must first find the device in order to identify the operator. Since the FCC generally does not provide RFI locating services, the burden became mine by default.

Some Typical RFI Sources

Switching-mode power supplies, usually associated with consumer electronic devices or battery chargers, often spew RFI at very high levels. They can emit signals in a regular and repeating pattern of spectral peaks, ranging from about 50 to 70 kHz, which exhibit a growling sound that may drift slightly in frequency. Such RFI noise “signatures” can sometimes help you distinguish between power line noise and noisy consumer electronics. If the audio noise bursts from your receiver seem to stand still on an oscilloscope with trigger-

ing set to LINE, the RFI might be power line related.

RFI from consumer devices that appears at regular intervals across the band likely comes from a switching-mode power supply. If the noise is pulsing it could be a battery charger. Sharp periodic ticks could be from an electric fence. Variable speed motors in appliances, like washing machines, increasingly rely on electronic speed controls and switching power supplies. See also *Light Bulbs and RFI — A Closer Look* for an additional discussion on FCC rules and interference from modern energy-saving light bulbs.¹

Locating the Noise Source

Power-line noise, especially if it affects only the lower frequency HF bands, can sometimes be caused by a source several miles away. However, if the source is a consumer device that meets the FCC limits, it most likely will be located in your home or a neighbor’s home. In this case, always start by temporarily turning off the main breaker to your residence while listening to a battery-powered radio. Also, disable any battery-powered devices. If the source proves to be external to your home, you can use the procedure from Mike Martin’s RFI Services web page to find the residence.² This approach works well when consumer

¹Notes appear on page 39.

Figure 1 — An RFI tracking system.

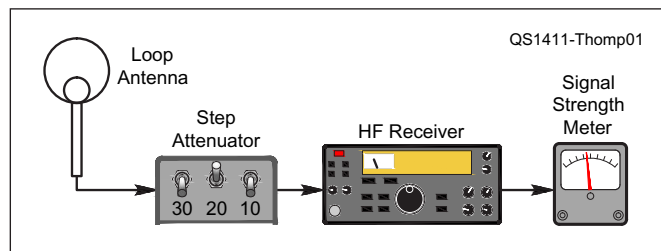


Figure 2 — Tracking loop antennas. Left to right: 24-inch copper loop, 20-inch aluminum loop, 16-inch #22 AWG wire loop with plastic tubing.



devices are within a few hundred feet of the ham. There are, however, some important exceptions.

Not Your Typical Source of RFI

In my experience, the most insidious and problematic RFI generators are high-power lighting systems, particularly grow lights used for cultivating plants indoors. Although classified as Part 18 devices, they are subject to similar emissions limits as Part 15 devices. Since these devices can cause detectable RFI for blocks if not miles, they would appear in many cases to be exceeding the FCC limits. One grow light tested in the ARRL Lab exceeded the applicable Part 18 FCC limits by 58 dB, and several that I have tested exceed Part 18 FCC limits by more than 40 dB. While the techniques in this article can be used to locate a wide range of RFI sources, my primary objective was to track down grow lights. Almost overnight, they had become the primary source of harmful interference affecting my station in Colorado.

Many amateurs keep a close eye on their RF background noise level. If an increase occurs randomly, and appears to coincide with periods of human activity such as weekends or evenings, it may be a consumer device. Power-line noise can also occur at random intervals but is often weather related. If, however, the noise comes and goes at regular intervals that appear to be controlled by a timer, then a grow light ballast is a likely culprit. These systems generally cycle on and off daily in approximately 12 to 16 hour intervals, although this timing sequence may vary depending on the plant. Another clue is the distance over which the interference can be heard. Typical consumer devices will fade away in 200 to 300 feet. Grow lights, on the other hand, can be problematic to well over 1000 feet.

So far in my neighborhood I have tracked down six grow light ballasts and three halogen light ballasts. Most of the grow light systems have been on a timer with a 12-hour on/off sequence. Some halogen yard lights, however, might be on a timer that is turned on and off at regular intervals. Grow light systems may also be off for a week or two during harvest, and can be on continuously during germination.

Both of these lighting systems, with the exception of a halogen desk lamp, can employ very high-current switching-mode power supplies. Some halogen systems

The Grow Light Problem

A very cooperative manager of a hydroponic store allowed Larry Benko, W0QE, and me (Tom Thompson, W0IVJ) to test some of his ballasts and lights. Also, one grower loaned me his equipment for the day during his "lights off" period. Using a line impedance stabilization network (LISN), we measured conducted emissions 40 dB above FCC Part 18 limits. The RFI in the HF spectrum from these ballasts can easily be heard a half-mile away. These products are available from multiple vendors; some have a sort of FCC sticker, but appear to have never been tested. The RFI is of such a magnitude that common mode ferrite chokes alone do not eliminate the interference. Larry and I developed filters that decreased the RFI from S-9 +40 dB to S-5 as measured on my IC-7000 from a short distance.^{A, B} Recently, an employee from the local power utility company said that about half of his RFI complaints were from grow light ballasts. In my experience, the 40 meter band seems to be where that sort of RFI is the strongest.

^Awww.w0qe.com/RF_Interference/grow_light_electronic_ballasts.html

^Btomthompson.com/radio/GrowLight/GrowLightBallastFilter.html

run multiple bulbs totaling several hundred watts on a 12 V system. Grow lights, on the other hand, can require more than a kilowatt. The radiating antenna is generally the house wiring and associated cabling. To be clear, the bulbs themselves, whether they are halogen tract lights or high-pressure sodium grow lights, are not the problem. It is the poorly filtered electronic ballasts that cause the problem. See the sidebar, *The Grow Light Problem*.

If you can determine the on/off sequence of the RFI, listen to your radio when the RFI begins. The noise sounds stronger and has a burbling sound to it until the lamp warms up, which is generally less than 5 minutes. A free program, *Audacity*, will enable you to make an excellent audio recording from your receiver audio output.³

Finding the RFI Source

Once you have an idea of what might be causing the RFI problem, you still need to find the source. Figure 1 shows a block diagram of the HF RDF system that I use. Grow light RFI is often prevalent in the 40 meter band, but a Yagi antenna is obviously not practical. A short dipole has directional characteristics only for horizontally polarized signals. RFI from consumer devices seem to be mostly vertically polarized. Besides, the short dipole needs a preamp to make it effective. The preamp must have sufficient dynamic range to prevent intermodulation from strong broadcast stations. One locating approach is to walk around the suspect area with a handheld shortwave radio with a telescoping antenna. The antenna can be shortened to help minimize the signal at ranges close

to the source. Driving around with a mobile rig can also work, especially if the source is some distance away. However, I found that a small tuned loop antenna used with a shortwave receiver and a good S meter (Figure 1) works best.

The Loop Antenna

A loop antenna is bidirectional. You can rotate the loop easily if you hold it above your head with the feed point at the bottom. In this position, vertically polarized signals peak when the loop is turned edgewise to the source. Additionally, a deep null in the signal occurs for vertically polarized signals when the loop is turned 90 degrees from the peak position. In other words, the signal is nulled when looking through the loop toward the source. That sharp null is most useful for determining the direction of the noise source since most consumer RFI seems to be vertically polarized as long as you are further than about one hundred feet from the source.

My loops are shown in Figure 2. They all consist of a tuned larger loop that is four times the diameter of the offset coupling loop. Note that the loop antenna efficiency is much lower than that of a full-size dipole. Signals are much weaker than what you typically hear with your base station antenna. The efficiency of the loop will increase as you increase the diameter of the loop or improve the conductivity of the tuned loop material. The coupling loop conductivity is less important.

As shown schematically in Figure 3, the larger loop is a tuned circuit and the coupling loop is a one-turn link into a choke

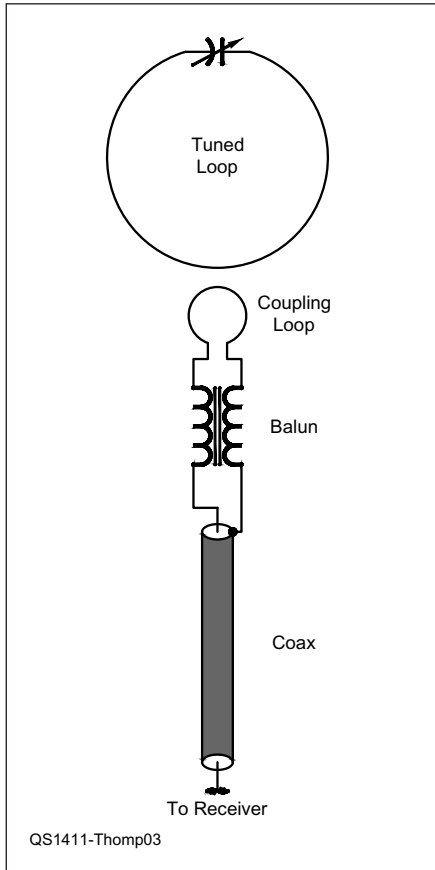


Figure 3 — Circuit schematic diagram of a tuned loop.

balun on the coaxial feed line. The tuning capacitor resonates the loop at the frequency of interest. A loop inductance calculator may be found on the web.⁴ [One-turn loop inductance is $0.016a[\ln(8a/b) - 2]$ μH , where a and b are loop and wire diameters in inches — *Ed.*]

I used a broadcast band capacitor with a built-in 8:1 reduction drive and a capacitance range of 16 to 390 pF.⁵ The 20 inch diameter loop made from 0.5 inch diameter aluminum has an inductance of 1.2 μH . Using

$$F = \frac{1}{2\pi\sqrt{LC}}$$

Table 1 Loop Antenna Details for 40 Meters		
Loop Diameter (inches)	Loop Material	Conductor Diameter Antenna Gain
24	Copper ¼"	-13 dBd
20	Aluminum ½"	-19 dBd
16	Copper 0.025" (#22 AWG)	-27 dBd

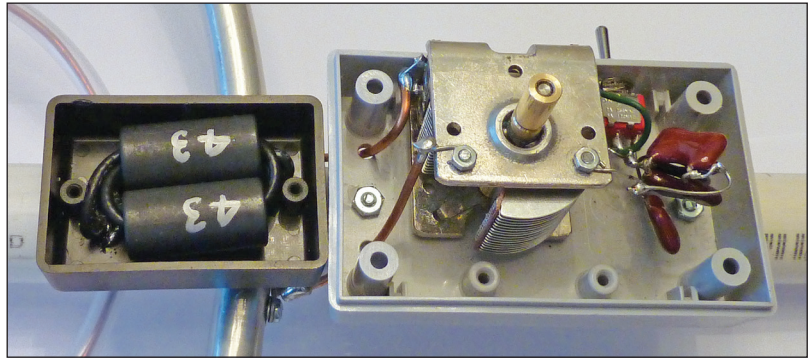


Figure 4 — Details of the 20-inch loop.

where F is frequency (Hz), L is inductance (H) and C is capacitance (F), we find that the loop can tune from 40 through 10 meters. You may need to make the loop slightly larger than 20 inches to cover the lower part of 40 meters.

The 5-inch diameter coupling loop of #12 AWG copper wire is encased in a piece of 0.25 inch plastic tubing. The balun is 3½ turns of RG-174 through two FairRite 2643540002 type 43 material cores (see Figure 4). I use an SPDT (center off) toggle switch to switch in 1200 pF for 80 meters and 5400 pF capacitors for 160 meters. The center off position is for 40 through 10 meters.

Loop Performance and Considerations

Connect the loop to your transceiver, making sure the transceiver cannot transmit. You can hear the noise level increase when you resonate the loop. Tuning is sharper. Even though the VSWR is not very low, I could measure the resonance with an MFJ259 analyzer on all bands except 160 meters.

Let's say that normal band noise is S-5 using a dipole on 40 meters, where S-9 corresponds to -73 dBm, and let's further say that your receiver minimum discernable signal (MDS) is -125 dBm. At 6 dB per S-unit, S-5 corresponds to -97 dBm (28 dB above the MDS). The three loops shown in Figure 2 have the characteristics shown in Table 1 for 40 meters. The 20 inch loop will hear the band noise 9 dB above the MDS of the receiver. Keep

in mind that antenna efficiency gets worse for lower frequencies, or smaller loops, or smaller wire diameters. If the RFI is much greater than the band noise, you may prefer the much lighter 16 inch loop. As you get closer to the noise source the RFI will become stronger so the RFI to band noise ratio improves.

The Step Attenuator

You may need a step attenuator when signals become very strong close to the noise source. I built a three-section Pi network resistive attenuator with 10 dB, 20 dB, and 30 dB sections. Combinations of these values will give an attenuation range from 0 to 60 dB in 10 dB steps. See Chapter 22 of *The ARRL Handbook* as well as *QST* for details.^{6,7}



Figure 5 — Noise receiver front view.

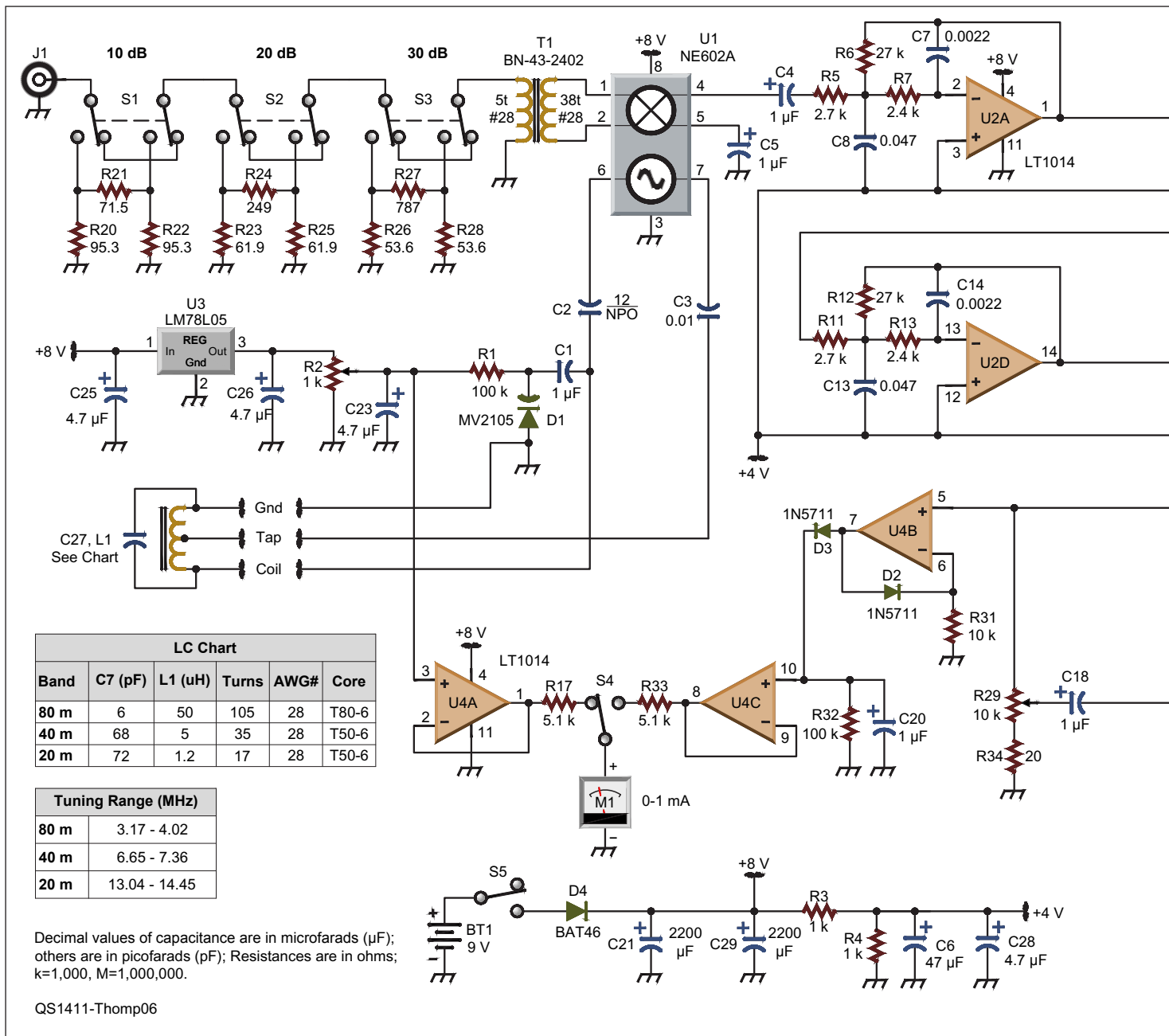


Figure 6 — Direct conversion noise receiver schematic diagram.

BT1 — 9 V battery

C1, C4, C5, C18, C20, C22 — 1 μF, 50 V ceramic capacitor

C2 — 12 pF, 25 V NPO ceramic capacitor

C3 — 0.01 μF, 50 V ceramic capacitor

C6 — 47 μF 16 V electrolytic capacitor

C7, C11, C14, C17 — 0.0022 μF, 50 V film capacitor

C8, C10, C13, C16 — 0.047 μF, 50 V film capacitor

C9, C12, C15 — 0.22 μF, 50 V film capacitor

C19, C24 — 100 μF, 16 V electrolytic capacitor

C21, C29 — 2200 μF, 16 V electrolytic capacitor

C23, C25, C26, C28 — 4.7 μF, 25 V tantalum capacitor

C27-80 m — 6 pF, NPO ceramic capacitor

C27-40 m — 68 pF, NPO ceramic capacitor

C27-20 m — 72 pF, NPO ceramic capacitor

D1 — MV2105 varactor diode

D2, D3 — 1N5711, Schottky diode

D4 — BAT46, Schottky diode

J1 — BNC female connector

J2 — stereo female connector

L1-80 m — 50 μH, 105 turns #28 AWG enamel on Amidon T80-6 core

L1-40 m — 5 μH 35 turns #28 AWG enamel on Amidon T50-6 core

L1-20 m — 1.2 μH 17 turns #28 AWG enamel on Amidon T50-6 core

M1 — 0-1 mA meter

R1 — 100 kΩ, ¼ W

R2 — 1 kΩ, 10 turn potentiometer

R3, R4 — 1 kΩ, ¼ W

R5, R8, R11, R14 — 2.7 kΩ, ¼ W

R6, R9, R12, R15 — 27 kΩ, ¼ W

R7, R10, R13, R16 — 2.4 kΩ, ¼ W

R17, R18, R19, R33 — 5.1 kΩ, ¼ W

R20, R22 — 95.3 Ω, 1%, ¼ W

R21 — 71.5 Ω, 1%, ¼ W

R23, R24 — 61.9 Ω, 1%, ¼ W

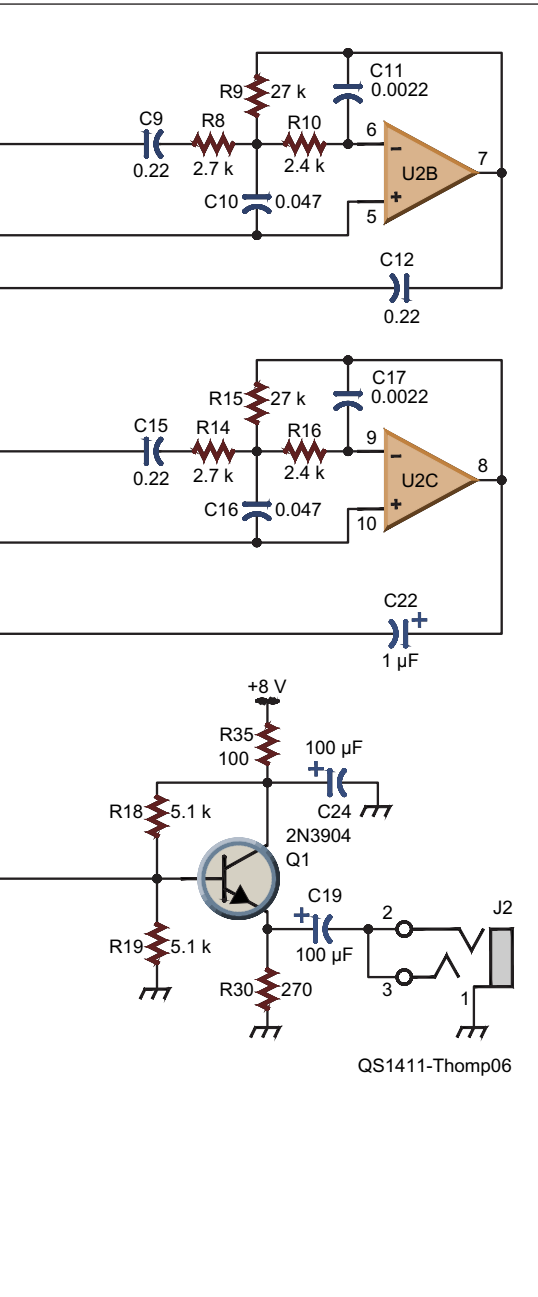
R25 — 249 Ω, 1%, ¼ W

R26, R28 — 53.6 Ω, 1%, ¼ W

R27 — 787 Ω, 1%, ¼ W

R29 — 10 kΩ potentiometer

R30 — 270 Ω, ¼ W



- R31 — 10 k Ω , 1/4 W
- R32 — 100 k Ω , 1/4 W
- R33 — 5.1k Ω , 1/4 W
- R34 — 20 Ω , 1/4 W
- R35 — 100 Ω , 1/4 W
- SW1, SW2, SW3 — DPDT toggle switch
- SW5 — SPST toggle switch
- T1 — primary 5 turns #28 AWG enameled, secondary 30 turns #28 AWG enameled on Amidon BN-43-2402 core
- U1 — NE602 or SA602 oscillator/mixer
- U2 — LT1014 or equivalent quad operational amplifier
- U3 — LM78L05, 3 terminal 5 V voltage regulator.

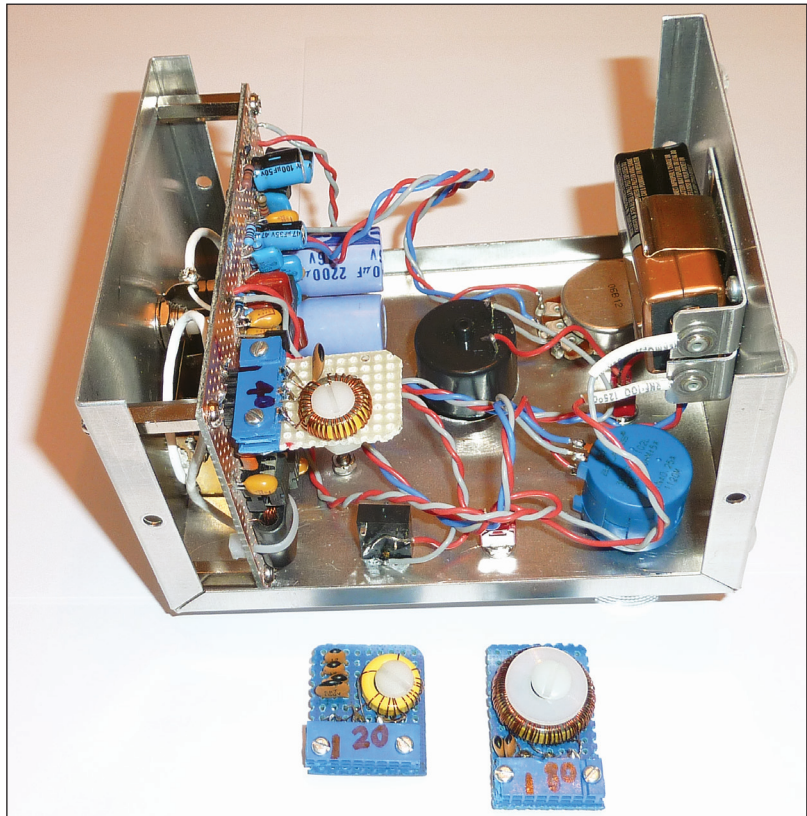


Figure 7 — Noise receiver inside view. The two modules are plug-in coils for 20 and 80 meters.

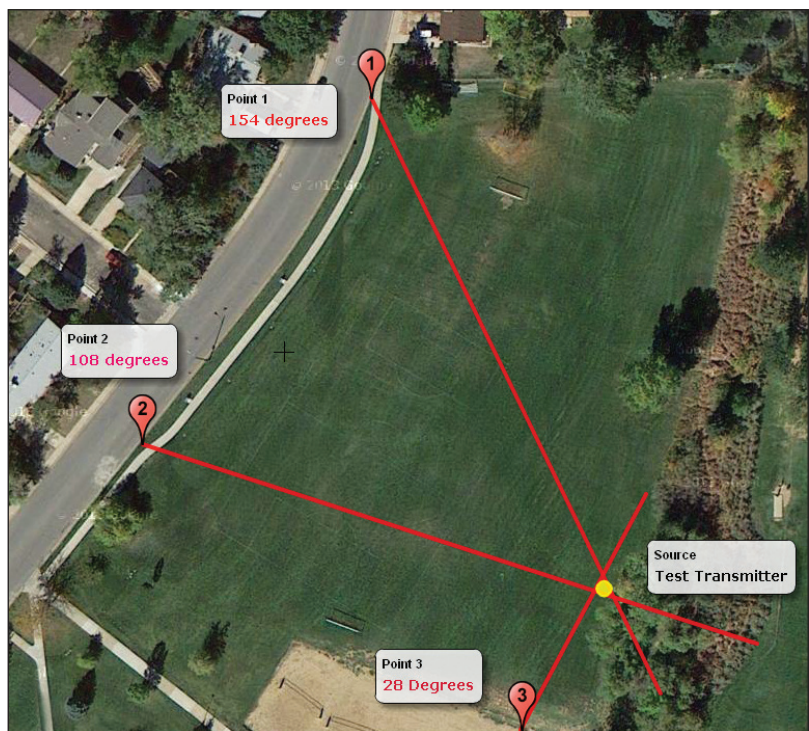


Figure 8 — Triangulation example using in a local park. [Image source: www.scribblemaps.com, copyright 2013 Google]

The HF Receiver

An AM receiver (FM will not work) that covers the HF bands (or at least the band where the RFI occurs) is essential. The shortwave receiver should have an external antenna jack and preferably a signal strength indicator. You can add an S meter, to an inexpensive receiver by finding the AGC line and amplifying it. The receiver must have good sensitivity with an MDS at least -120 dBm. You can use a small transceiver like the FT-857D, FT-817, DZKit HT-7, or IC-7000, but make sure that it cannot transmit.

I built a small direct conversion receiver (Figure 5) with a built-in attenuator, S meter, and battery. The circuit diagram is shown in Figure 6, and construction technique is shown in Figure 7. The NE602 IC is used as an oscillator and mixer. The audio output from the mixer is filtered and amplified by four of the amplifiers in the quad package. Each operational amplifier is an active low-pass filter with 20 dB gain per stage. Between amplifiers, ac coupling provides a low frequency roll-off at about 200 Hz. The high frequency roll-off is at 3 kHz with 48 dB per octave attenuation in the stop band. Another quad operational amplifier provides buffering and detection. The NE602 oscillator is a varactor-tuned Hartley with plug-in coils for 80, 40, and 20 meters. The varactor diode is tuned with a 10-turn potentiometer, and a meter reads the varactor voltage to give an indication of the received frequency. Since the NE602 has a conversion gain of about 20 dB the total gain is about 100 dB. The input impedance of the NE602 is $1500\ \Omega$ so I used a broadband transformer with a 5:1 turns ratio to match a $50\ \Omega$ input. An emitter follower drives a pair of low-impedance headphones. Also, the output of the last active filter is rectified using an active detector and a peak detector. I use the same meter to read the varactor voltage and signal strength. This receiver has an MDS of better than -130 dBm.

If you are tracking down a noise source that is on a particular frequency, transmit a carrier on that frequency with a small wire connected to the noise receiver antenna. Locate the carrier and note the varactor meter reading. You should be able to tune in the RFI source using the varactor meter reading. Since this is a direct conversion receiver, you will hear both upper and lower sidebands simultaneously. The receiver is exactly on frequency when you hear a

zero beat between the tones heard on the upper and lower sidebands as you tune the receiver.

Learning to Use Your RFI Detecting Equipment

I built a small test transmitter (see the *QST* in Depth web page for the details) to practice using the equipment.⁸ The little transmitter radiates a small signal on 7159 kHz. You can orient it for either vertical or horizontal polarization and practice locating it. I found that the horizontally polarized signal is much weaker than the vertically polarized signal at various distances.

With the test transmitter oriented vertically, turn your loop edgewise to the source to get a peak while determining if the signal is getting stronger or weaker. Orient the loop broadside to get a null to determine the direction of the source. Using vertical polarization works in most cases for finding grow light RFI. Larry Benko, W0QE, and I have spent some time learning search techniques.⁹ With a little practice, you will become an expert at locating the test oscillator.

Locating RFI in Sources

Locating a known RF test source and locating an unknown RFI source can be very different. With an unknown source, the direction and polarization are not known. However, I have found that assuming a vertical polarization initially is a good start.

Tracking a Source

Use the following as a guide to tracking a source.

- (1) If you can hear the RFI on the loop near your house, tune the receiver so that only the noise source is heard. Twist the loop for maximum signal while holding the loop over your head.
- (2) Walk in the direction that the edge of the loop is pointing. If the signal gets weaker, walk in the opposite direction while continually twisting the loop for maximum signal. As the signal gets stronger, switch in more attenuation to keep the S meter at about half scale.
- (3) Once the signal is strong, twist the loop for a null and continue to walk in the same direction; now you will be looking through the loop for a refinement in direction.
- (4) Alternate between maximizing the signal strength and refining the direction until you think you have located the RFI source.

Triangulating a Source

You can triangulate to find the source. In addition to your locating equipment you need a magnetic compass. Calibrate the compass for the magnetic declination for your area (see www.ngdc.noaa.gov/geomag-web/#declination). Use the following steps as a guide.

- (1) Take a reading at your house and rotate the loop for a null. The RFI source should be located along the line perpendicular to the broadside of the loop.
 - (2) Walk about 500 feet perpendicular to the direction from the line where the null occurred and find another null. The RFI source will again be located along the line perpendicular to the broadside of the loop.
 - (3) The lines should cross at the source and diverge beyond the source. Hold the loop in front of you and rotate your body back and forth until the null is well defined. Site an object on the landscape by looking through the small coupling loop. Point your compass at the object and record the reading.
 - (4) Repeat steps (2) and (3) after moving about 500 feet in the other direction from your house.
 - (5) Go to www.scribblemaps.com, click on *Create Your Map Now*, and type your street address, city, and state in the *Search* window. Use the \pm controls on the top right to zoom so that all of your reading points are on the map. Use the *Draw Lines* command to draw lines from each point using the compass readings you recorded. Zoom so the intersection of the two lines is on the map. Now pick a place on the map so that a new line can be drawn perpendicular to one of the two lines on the map. Go to that location with your loop and receiver and get another compass reading using the null method described in step (2). Place this line on the map just as you did previously. Due to measurement errors, these three lines will not intersect in a point but will form a triangle instead. This is the triangle of confusion. Ideally the RFI source lies within or near this triangle.
 - (6) Go to the triangle location on the map with your equipment and zero in on the source.
- Figure 8 shows the results of this process when it was performed using the test transmitter and done in a nearby park. If you are not sure that you have compensated your magnetic compass correctly for magnetic

declination, you can use *Scribblemaps* to get a vector down your street and see if it agrees with your compass.

Next Steps

After you think you have located the RFI source, make sure you have the correct house. I generally move across the street and walk up and down to make sure the loop is pointing to the correct house. [Close by, say within a half wavelength separation, the patterns of loops and sources may be dramatically different than far away. — *Ed.*] If you have determined the time when the RFI turns on, verify from across the street that you have the correct house.

At this point, take care. If this is an indoor growing operation, you do not know what could be growing in that house. You know your neighbors and the nature of your neighborhood better than anyone else possibly can, so use your own good judgment about how to approach a neighbor, or even whether you should approach the neighbor at all. Approaching a total stranger about an interference problem can result in unfortunate reactions. People can be dangerous, so approach a neighbor only if you feel completely comfortable and safe. ARRL can write letters to a neighbor on your behalf, anonymously if you wish (but if you have a visible ham antenna, it is likely that your neighbor will have a pretty good idea where the complaint originated).

Fixing the Problem

In most cases the problem can be fixed.

Generally, it is not a good idea to do any work on your neighbor's equipment. You might feel comfortable applying external filters to solve RFI problems with some neighbors, but use your judgment. Commercial filters that might do the job are available, but I have not tested any of them.^{10, 11} You need a differential and common mode current filter on the ac line that can handle the high current that these lighting systems require.

Your neighbor might not even cooperate with you to turn off the power, much less let you install filters on the system. If you do not get any cooperation, consult the ARRL on how to proceed. The FCC is just beginning to be aware of the magnitude of this problem, so a letter from the ARRL might be your best solution at this time.

Conclusions

RFI on the amateur bands is a growing problem. You can build the equipment to track down the RFI. You can also remedy the problem in most cases if you have a cooperative neighbor. The ARRL considers this to be such a problem that it has devoted a web page to it.¹² This web page covers the legal as well as the technical aspects of the problem.

I would like to thank Larry Benko, W0QE, for sharing his transmitter-hunting skills and for his technical support with this article.

Notes

¹M. Gruber, "Light Bulbs and RFI — A Closer Look", *QST*, Sep 2013.

²www.rfiservices.com/residence.htm

³www.audacity.sourceforge.net/download/

⁴www.eeweb.com/toolbox/loop-inductance

⁵www.midnightscience.com/catalog5.html#part3

⁶Chapter 22 in *The ARRL Handbook*, Centennial Edition. ARRL order no. 0007, available from your ARRL dealer, or from the ARRL Store, Telephone toll-free in the US 888-277-5289, or 860-594-0355, fax 860-594-0303; www.arrl.org/shop/; pubsales@arrl.org.

⁷R. Shriner, WA0UZO and P. Pagel, N1FB, "A Step Attenuator You Can Build," *QST*, Sep 1982, p 11.

⁸www.arrl.org/qst-in-depth

⁹www.w0qe.com/RF_Interference/tracking_down_rf_interference.html

¹⁰www.cor.com

¹¹www.morganmfg.us/radio-products/ac-line-filters-protectors/

¹²www.arrl.org/grow-light-rfi

Tom Thompson, W0IVJ, holds an Amateur Extra class license. He was first licensed as K5BHB in 1955 in Odessa, TX at age 14. Tom received a BA in psychology in 1963, and a BS in electrical engineering in 1969 from the University of Colorado in Boulder. He worked in electronics for the Department of Commerce at the Central Radio Propagation Laboratory at the National Bureau of Standards (now NIST) and National Oceanic and Atmospheric Administration (NOAA) for 44 years. He has applied his Amateur Radio knowledge to several projects during his career. Now retired, Tom devotes his time to designing and building Amateur Radio equipment. He is an active member of the Boulder Amateur Radio Club. You can reach Tom at w0ivj@arrl.net.

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