Lab Notes

Prepared by the ARRL Laboratory Staff

Different Grounds for Different Shacks

This month's column features Mike Tracy, KC1SX, ARRL's Technical Information Service (TIS) Coordinator. Mike answers a wide range of technical questions for hams every day. Questions about grounding stations in difficult locations are common here at HQ.

Q Mike, I need some help! I move around a lot and set up my station differently at each location. Can you give me some grounding advice that applies everywhere?

A Although no grounding advice is universal, I can help with some general information. There are three types of station "ground" to consider RF-signal ground, electrical-safety ground and lightning-protection ground. (We call many other things "ground," too, but we're dealing only with station grounds here.) Each of these grounds requires different methods, techniques and hardware to be effective.

An effective RF ground ensures that the operating position is at a low RF voltage by providing a low-impedance path for unwanted RF. We call this low-impedance point an *RF ground*, but remember that it takes many forms other than a connection to earth.

An *electrical-safety ground* helps protect the operator from dangerous ac-power-system shocks. A *lightning ground* diverts *some* lightning-strike energy away from your station. Although we need separate RF, safety and lightning grounds, building codes require that we electrically bond all grounds to the ac safety ground, outside the building—more on this later.

Q Doesn't a station require a good ground to work properly?

A Surprisingly, no. If it did, none of us would ever be able to work through a satellite station! With balanced antenna systems, such as dipoles and Yagis, the antenna does not require an RF ground to function well. With other systems, such as longwires and some types of vertical antennas, an RF ground connection is important to good performance. In these cases, the antenna ground is distinct from any equipment grounds.

Q What kind of RF-ground problems might I encounter?

A The most common problem is "RF in the shack." The result can be a tingling sensation or RF burns as you touch your microphone, key or transmitter chassis. This stray RF may interfere with station circuits, making the SWR meter needle jump, SWR-protection circuits reduce power when they shouldn't, keyers continue sending after you release the paddles, etc.

Q So that explains my problem on 15 meters! It is pretty severe; what should I do?

A There are several causes of RF in the shack, and the cure depends on the cause

1. RF currents on the coax shield may result from antenna radiation, shield leakage or omitting baluns at transitions between balanced and unbalanced system components. These currents simply flow onto station equipment via the chassis ground connections.

To eliminate them, add baluns as needed. Block currents with a common-mode choke, cable choke or a W2DU (bead) balun where the feed line enters the shack, and establish a low-impedance RF ground. [1]

2. RF may couple directly to nearby conductors when there is a high RF voltage point in the shack. End-fed random-length wire antennas often place an RF high-voltage point at the back of the antenna tuner. This situation is best treated by changing the antenna length in small increments (±1/8 λ). Some stations also require an RF ground.

3. RF may appear in a shack located too close to the transmitting antenna, eg an indoor antenna. Such RF may be a biological hazard. Read the ARRL's RF Awareness Guidelines in *The ARRL Antenna Book* or *The ARRL Handbook.* Try changing to low-power operation or moving the antenna or station location.

An RF ground may cure problems from causes 1 and 2. A physical connection to earth ground, however, is not as easy as it sounds.

Any ground wire has physical length, so it functions as a ground wire and an *antenna*. A wire of significant length (0.1 λ, or longer; less than 5 feet on 15 meters) radiates RF energy on the way to earth, and the wire's input impedance varies with its length. [2] For example, a 1/4-λ ground wire transforms a low-impedance ground termination to a high impedance at the transmitter—hardly an RF ground at all. Therefore, earth grounds are more practical at lower frequencies, 80 or 160 meters, than at higher frequencies. What can we do? There is an answer: a radial system.

By connecting a 1/4-λ wire to the transmitter ground terminal, we ensure that the transmitter chassis is at a low impedance for the radial's resonant frequency and odd multiples thereof. (We commonly call such wires counterpoises, but that's a misnomer.) The radial *acts* as a lossy 1/4-λ monopole with its low-impedance feedpoint at the back of the transmitter. It sucks away any RF near its resonant frequency and radiates it.

The radiated RF may still affect instruments in the shack; experiment with placement of the radial until everything works properly. With any reasonable antenna system, the RF radiated by the radial should not be hazardous. Use insulated wire and insulate the unterminated end to prevent RF burns. Finally, radials are frequency sensitive; you'll need one for each frequency with RF problems.

Q I live in a third-floor apartment. Can I run a ground wire from there?

A Connecting to earth from three stories up is a tougher challenge. Because the radial solution I just described is convenient and inexpensive, try that first. If you still have problems, install an earth ground to see if it helps. Here's how

Locate your shack on an outside wall and run the ground conductor down the outside of the building. Don't try to pinch pennies here! If possible, use copper strap, sold as *flashing copper*. Its wide, flat surface gives it a much lower impedance than a round wire. Whether using strap or wire, purchase the largest size you can afford.

A single ground rod does not neces-sarily provide a low-resistance earth connection. There are several ways to improve the connection. In order of preference, you can: lengthen the ground rod; use multiple ground rods (at least 6 feet apart); treat the soil to make it more electrically conductive.

Q Could I use a cold-water pipe instead?

A No, this is not wise. Although this was common amateur practice for decades, the *National Electrical Code (NEC)* requires that metallic water pipes be bonded to, and part of, the electrical-safety ground system when they are continuous with the directly buried outdoor service water piping. [3] The *NEC* also requires that installations prevent any objectionable currents from flowing over these grounding conductors. Even if not connected to the *NEC* grounding sytem, short lengths of isolated metal water pipes could become energy radiators (antennas) and safety hazards (RF burns) if used as RF grounds.

Q I have heard of an "artificial ground." What does it do?

A An artificial ground is an antenna tuner for your ground wire. It transforms whatever impedance exists on your ground wire to a low impedance. Used in this way, it can solve some grounding problems. Even so, the ground lead may be an effective radiator. In that case, this technique may increase RFI problems, rather than solve them.

Q The third wire of my electrical outlets is grounded at the circuit-breaker box. Can't I use that for my RF ground?

A No. As noted above, the *NEC* requires that installations prevent any objectionable currents from flowing over these electrical-safety grounding conductors. The electrical safety ground prevents shock hazards from devices plugged into the ac line. In case of an insulation failure that places an ac voltage on the equipment chassis, the safety ground ensures that the protective circuit breaker trips, protecting the operator from a dangerous electrical shock. Any RF signal imposed on the safety ground system causes energy radiation throughout the building; poses a health and safety hazard (eg, ground-fault interrupters [GFCI] may malfunction) and may damage appliances connected to the building wiring system.

Q Thanks, Mike. You and the *Handbook* have answered my questions about RF and electrical safety grounds. Where else can I learn about electrical safety?

A Electrical safety and requirements are covered in the *NEC,* but the Code is not intended for nonprofessionals! Fortunately, the publisher also publishes the *National Electrical Code Handbook,* which interprets the Code. This book is intended for professionals, but most technical hams should be able to use it to *understand* the *NEC*. Remember that *only* your local building-code regulations define the actual requirements in your locality. Consult with your local Building Inspector and a licensed electrician to learn how the electrical codes apply to your station.

Q What about lightning grounds?

A *Proper lightning protection is a job for professionals.* The Safety chapter of the *Handbook* provides information on how to locate a professional to help with your installation.

Q Before I call the experts, I would like some information. Where should I look?

A In addition to the *Handbook*, look at the Lab Notes columns in October and December 1994 *QST*. These columns have been combined into the TIS information package “Lightning Protection,” available from the ARRL Technical Department Secretary (League members $2, nonmembers $4, postpaid). The text of Lightning Protection is available at no charge from our Internet FTP archive site and e-mail InfoServer. [4]

Q Okay, but I want to know more right now!

A All right, but *do* get the other articles. Because a lightning strike contains RF and lower frequencies, you need a low-impedance RF ground system to carry and dissipate many millions of amperes. In addition, lightning protection systems must ensure a safe path to the earth—*outside all building structures!*

Lightning strikes follow the path of least impedance to ground. Any quick impedance change, even a moderate bend in the ground leads, encourages a jump to nearby conductors—possibly inside your home!

Install an entrance panel for your feed lines and control cables. You can make a panel from heavy copper sheet (1/8-inch minimum thickness), bent into a box shape. Position this panel on the outside of the house, at least 4 to 6 inches away from combustible materials. Connect the panel to the ground-rod system with a short conductor, as straight as possible. Copper strap is best for this conductor, but heavy wire (see the *Handbook* for information on grounding materials) will work nearly as well. A single ground rod is usually insufficient as a lightning ground. A good system has three or more eight-foot ground rods, spaced at least six feet apart.

Provide a connector and lightning protector/surge arrestor for each antenna feed line and rotor cable. Install these devices, per the manufacturer’s directions, on the outside of the entrance panel. Install appropriate connectors at the ground-rod system and transfer your feed lines and cables from the panel to the ground system whenever you are not using your station.

Outside the entrance panel and building, route all feed lines and cables at least six feet away from metal objects (electrical raceways, piping, wiring, enclosures, door and window frames, and other noncurrent-carrying metal parts). This will keep lightning from taking an unintended side track.

Q Do I need an entrance panel for my third-floor apartment? It sure would attract attention!

A For proper protection, yes. Fortunately, the panel—as well as the wire leading down to the ground rods—can be painted to match the exterior of the building. It’s unnecessary if you use an indoor antenna, in which case your probability of a lightning strike is minimal.

Q What if I have a tower? How should I protect it?

A Ground the coax shield to the tower top and where the coax leaves the tower. This prevents voltage differences between the tower and cable during direct or nearby strikes.

You must establish multiple ground paths to divide and dissipate the lightning energy. Connect each leg of the tower to its own ground rod, via a heavy strap. Connect all metal guy wires to ground rods. Use stainless-steel hardware between galvanized metal (which has a zinc coating) and copper grounding materials to prevent corrosion.

Q Is there anything else I should know?

A Yes. Don't solder any lightning ground connections! Solder is quickly destroyed by the heat of a lightning strike. Use sturdy, noncorrosive mechanical connections.

Finally, as noted earlier, you must connect (bond) all of your grounds together to prevent dangerous voltage differentials. Although RF, electrical-safety and lightning ground systems require separate sets of hardware, the *NEC* requires that we bond all three systems together. This includes the RF ground, lightning-protection grounds, the electrical-safety grounding-electrode system, cable-television ground and telephone service ground. The size of the bonding conductor depends on the size of wire used in your electrical service entrance. Contact a licensed electrician, professional engineer or building official to assist you in meeting the bonding requirements of *NEC* article 250-81.

Notes

[1] Common-mode chokes and their construction are discussed throughout *Radio Frequency Interference How to Find It and Fix It* (from ARRL, Order No. 3754). Especially see Figure 12 on page 5-12. Baluns and their construction are explained in Chapter 26 of *The ARRL Antenna Book,* 17th edition, ARRL Order No. 4734*.*

[2] This follows from Ohm's Law and the voltage and current distributions on resonant antennas. For more information, see Chapter 2, and the discussion of Delta Matching, on pages 26-17 and 26-18, of *The ARRL Antenna Book*.

[3] National Fire Protection Association, PO Box 9101, Quincy, MA 02269-9101; tel 800-344-3555; Web Site: **http://www.wpi.edu/~fpe/nfpa.html**

[4] To obtain this file by e-mail, send a message to our Internet *Info Server* as described under Technical Information Server on page 10 of this issue. Substitute "**send lightnin.txt**" for the line "**SEND INDEX**" in the example on p 10. You can also find this text on the World Wide Web at **ftp://oak.oakland.edu/pub3/hamradio/arrl/infoserv/tech/** or one of the mirror sites listed on the ARRL Web home page.