The Station Ground System

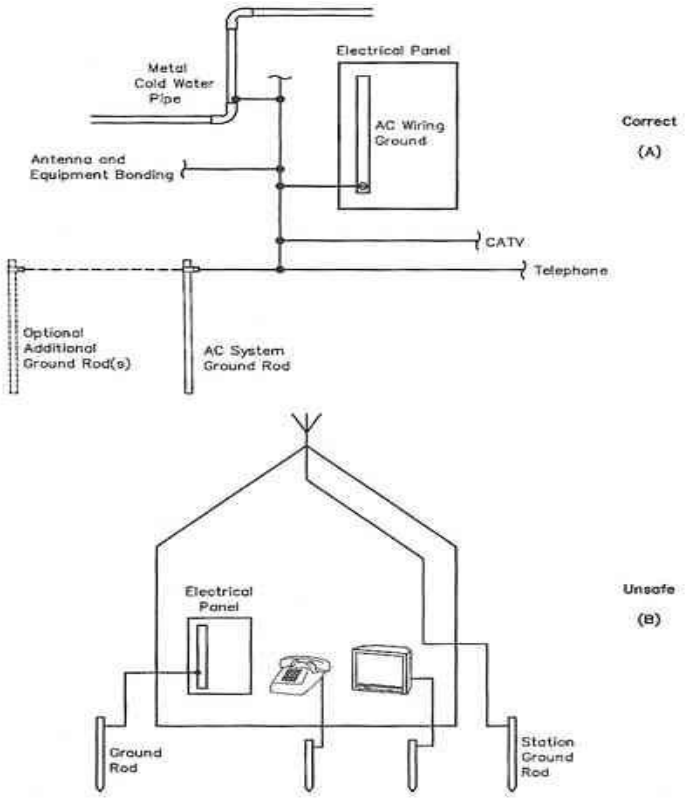
Our discussion this time is not specifically about SWR, but about one of the contributing factors to unacceptable SWR and poor signal propagation – improper grounding.

RF ground and Electrical ground are not the same

There are a number of lessons to be learned on this subject, not the least of which is the difference between grounding for proper conduction and radiation of RF, and maximum protection against lightning damage and electrical shock hazard. Quite often there is ignorance to the fact that the two are not synonymous. They are, in point of fact, quite often at odds with each other.

Good electrical ground techniques seek to protect the user against power line AC power line hazards and destructive intrusion by lightning. Good electrical grounding is mandatory, both by local and national electrical codes, but also by good engineering design of your ham station. So, if we construct our station to comply with NFPA, National Electrical Code, and local electrical codes, is this sufficient to provide a good RF signal path for our station? The answer is not a straightforward one. In ham radio we must consider the electrical code, but also consider our signal path to ground. Let's concentrate on the electrical systems protection first.

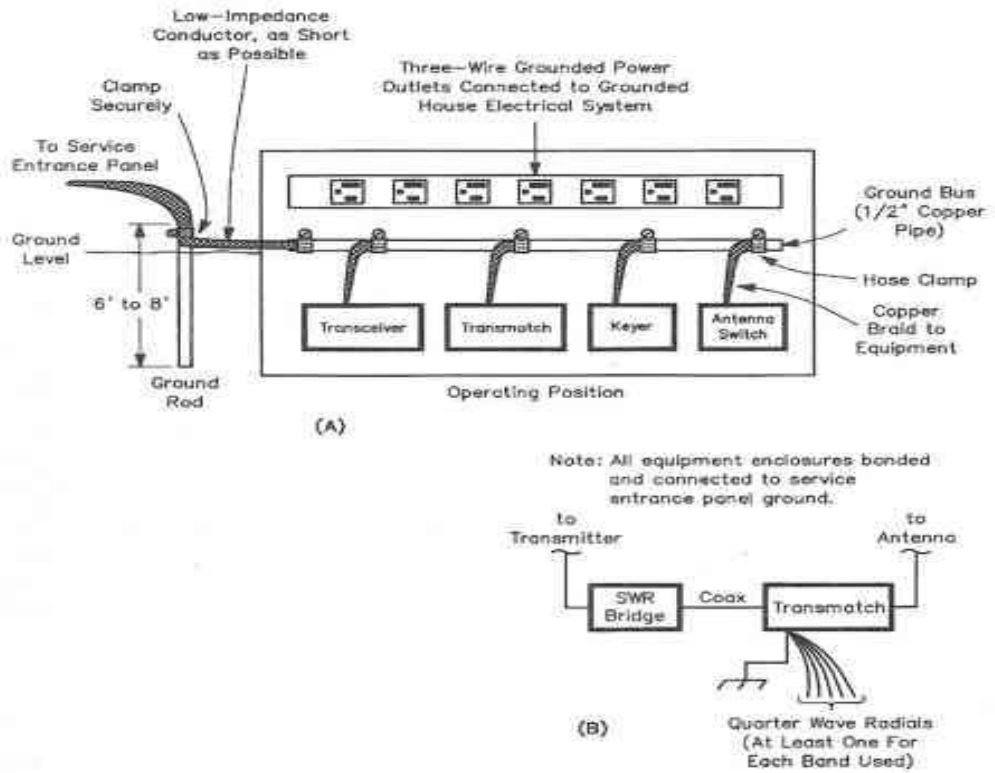
Consider the following diagram of two grounding methods. The method employed in (b) of the diagram may appear to have the best protection since there is a direct path to ground from each appliance. The fact is, that it is not only inadequate, it is not compliant with any accepted electrical code, and does not follow accepted guidelines for electrical shock hazard and lightning protection.



What about the station gear, and tower, rotor, and computer? Do we use method (a) in the illustration. Again the answer is not simple as you think.

As you evaluate the next illustration, notice the difference between electrical connections for AC power, and RF connections for control of transmitted signals.

Both diagrams are vastly over-simplified. Your particular situation may be much more or much less complicated.



An effective station electrical ground bonds the chassis of all station equipment together with low-impedance conductors and ties into a good earth ground as near as possible, or where the electric service panel has its origin. Notice the very large ground bus in the illustration above. All the chassis of station equipment are bonded together and connected to an earth ground, while AC power utilizes the ground provided by the electrical distribution box. Although not shown, lightning protection should also be provided by arrestor type devices on antenna, control cables, and power lines, having the a single earth ground connection common to each.

In multi-level or large sprawling structures, care must be taken to bond to the closest earth ground source (this is not to say a cold water pipe). If one is not available, a separate bonding ground wire should be run to the nearest earth ground. In most cases the best approach is to drive one or more ground rods into the earth near a window or access point to the station. Bonding to this ground rod will provide needed protection against electrical hazards and provide **some** lightning protection. If your soil is soft and contains few rocks, an acceptable alternative to the 8 ft copper clad rods from an electrical supply house, is ½ " heavy-wall copper water pipe pounded in to a depth of at least 4-5 feet. Since this material is relatively soft, care should be taken when driving it into the ground as it will bend quite easily. Bonding to a conventional ground rod or a copper pipe alternative should be of good electrical quality and above ground, outside connections should be weatherproofed as much as possible.

Unexplained noise can creep into station systems where ground systems develop high resistance or noisy connections to ground due to corrosion and oxidation. This is especially true where the station is near salt water shores.

Operators who enjoy the upper frequencies should pay particular attention to the length of the connections from equipment to ground rod. The length should be as short as practicable so as to avoid resonant lengths to ground that may cause *ground-looping* noise and RF high voltage on the station

equipment chassis. To illustrate this, consider a length of grounding cable (regardless of size/gage) measuring about 33 feet (not atypical for a two story dwelling). If the operator is transmitting on 20 or 40 meters, this length is very near a fractional wavelength of these frequencies. It is not inconceivable to imagine that sympathetic oscillations may occur on the ground conductors in these bands due to the length being near a resonant wavelength. In such a case, the ground becomes an unwitting and unwelcome sympathetic radiator. In situations where upper level dwelling installations cannot obtain an adequate RF ground, an artificial ground device may be used between the antenna and transmitting equipment to provide the needed RF ground. This type of artificial ground is a last resort solution.

Lightning protection

Protection against lightning on a comprehensive level is a complicated and controversial subject that has been published at length.

A lightning ground system should be capable of dispersing large amounts of electrons from a strike over a wide area with minimum ground potential rise. It should be capable of doing this very quickly (fast transient response). By spreading electrons out over a wide area with a fast transient response ground system, the ground potential rise (step potential) for any smaller given area would be reduced. The speed, or transient response, of the ground system would be dependent on the combined inductance of the below grade conductive components and the resistivity/conductivity of the soil "shunting" those components. The lower the inductance of the system components and soil resistivity, the lower the impedance at higher frequencies, the faster the ground system could disperse electrons. Copper strap has lower inductance per unit length and more surface area in contact with conductive soil than the equivalent amount of copper in a circular conductor.

Any signal line with a ground return through the input/output circuitry is subject to damage. The local elevated potential would seek to equalize the signal conductor through your circuitry, and use it as a path to a lower potential. Local and remote interconnected equipment would be at risk. A coaxial cable shield can carry a large amount of current at speeds exceeding 90% the speed of light with possible damage at both ends. The velocity factor of the coaxial cable center conductor with a fast rise time pulse can vary from 66 to 90% the speed of light. The directly applied or induced voltages on the center conductor would "roll off" and arrive after the shield pulse, producing large differential voltages between shield and center conductor. Catastrophic damage to coaxial cable and/or equipment is often the result.

Secondary AC power conductors are a two way "street" for electrons. They are usually large low inductance conductors. A strike to the power lines some distance away can conduct damaging energy to equipment. Also, a strike to the tower or building can produce a local ground potential rise with damage to your equipment from energy attempting to "escape" to the outside world through the AC secondary conductors. [Tech Notes, PolyPhaser © 2009 Protection Technology Group]

Some of the best information on lightning protection is provided by Polyphaser Corp. in their quarterly newsletter and on their web site:

http://www.polyphaser.com/technical_notes.htm

Very safe rules of thumb for lightning protection grounding are:

1) Make the route to ground with as **large** a **conductor** as possible (use copper strap if possible) in as **straight** a **line** as possible and as **short** as possible.

2) Avoid sharp bends or loops in the grounding conductors as well as pointed or sharp edges on connections.
3) If in doubt about whether there is adequate conduction for lightning protection, THERE ISN'T!
4) Never take a chance – disconnect completely all outdoor antenna from station equipment during severe weather that contains close dangerous lightning. If possible unplug equipment from electrical outlets and telephone/cable lines.
5) Never operate under close dangerous conditions. Turn it off and unplug it.

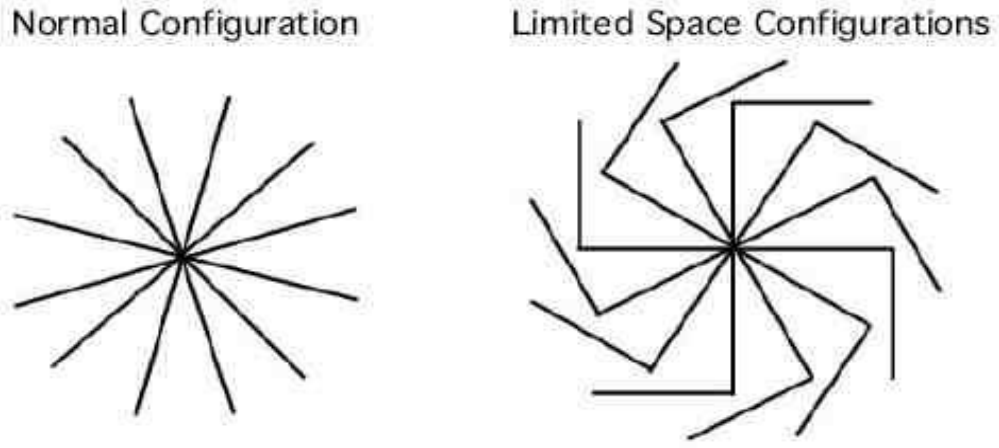
The station electrical, and to a lesser extent the RF, grounding system provide protection against hazards from equipment and lightning in the shack. However, the use of artificial grounding methods also has a place where antenna efficiency is concerned - at least in the case of vertical ground mounted antennas (reference our discussion earlier).

Stationary Antenna RF Grounding

As we discussed in a previous chapter, inadequate ground currents in a vertical antenna can cause losses contributing to radiation inefficiencies. To lower the power losses in ground system absorption, an artificial ground plane may be constructed to improve ground currents. This artificial ground plane is primarily multiple wires of fractional wavelength radiating in all directions from the antenna axis and connected to the ground or shield of the antenna system. Wires of this type should be distributed in regular equally spaced fashion in all directions. Often, limited space applications do not allow ground plane wires to be placed in a straight line in all directions. When this is the case, radial wires may be curved or bent at an angle about half way the length of each. This provides a shortened umbrella, but a proper RF ground. The number of radials needed for maximum efficiency ranges from 8 to 128 (nominally 12-18) depending on frequency, soil type, antenna height, and cost of construction. The next illustration shows the two common methods described.

In this way the impedance of the ground structure is lowered and overall losses to dissipation (called I^2R ground-return loss) are reduced to negligible values. The reduction of ground absorption loss improves overall efficiency and as a result - available power radiated is greater.

Variations and permutations of this altered pattern are not only possible but very workable in practice. The object is to provide an efficient ground plane for the vertical element in the limited space available.



Courtesy DX Communications Products

RF grounding considerations are not limited to vertically oriented antenna types. As we have discussed in previous text, a common RF ground is prudent for elimination of possible RF hazards caused by high-power or high-SWR levels.

Mobile installation and grounding

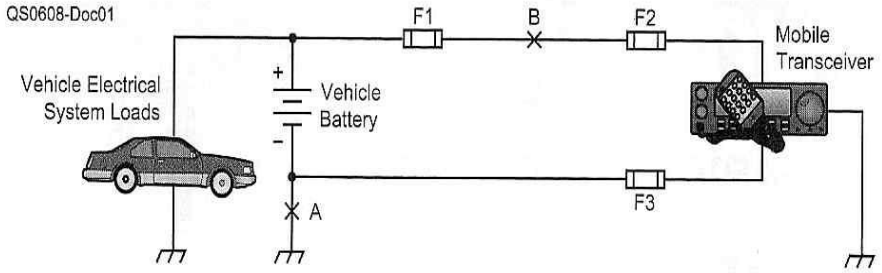


Figure 1 — Simplified schematic of a vehicle electrical system showing radio connections directly to the battery and fuse positions.

Before we move on, let us discuss the case of mobile installation. The ground for this system is the auto body or frame. As more and more body parts are becoming non-metallic, the use of the metal frame or body as a common ground conductor is more important than ever. Modern automotive electrical systems require care be taken so as not to cause RF currents in and around the on-board electronic devices and appliances (the engine computer, GPS, DVD Player, etc.). Proper methodology for mobile operations would be to make all ground connections for RF as near the same point as possible. The illustration above shows a typical mobile installation, greatly simplified. The "X"denotes potential places where trouble may occur and points out why fusing is placed in both the + and - leads of the battery.

Otherwise, insure that the antenna, radio, and battery share the same electrical ground conductor and it is as low a resistance as possible. External connections should be protected with auto body undercoat or some other spray on protective coating to minimize corrosion by weatherproofing the connection.

Do not depend on the coax shield to provide the ground connection for the antenna. If the base of the antenna is not a solid, bare-metal connection to the same ground conductor as the battery and station radio, run a separate low-impedance ground conductor to it from the antenna (this includes mobile antennas mounted on a removable towing bar).

Do not use the metal dash superstructure as ground for the transmitter – find a suitable ground to the body superstructure. If necessary, run a shielded plus and minus battery lead directly from the battery [Note: it should be obvious to you by now that the shield connects to the auto chassis and the negative lead to battery negative and/or chassis ground] to the radio to avoid engine noise being picked up inside the engine compartment or RF traveling from the station radio to the engine or ignition computer.

If engine ignition noise is a problem in receiving, a very flexible grounding lead may be bolted to a metal hood from the grounding frame to provide greater shielding effect. Resistive inserts (like resistive plug wires or caps) reduce noise at the expense of poor engine performance on older cars. Do not use these devices on any recent model car as they do not work and may stop your engine from running.

Where battery positive is routed through the firewall or under decorative escutcheons next to the frame, fusing is necessary <u>at each end of the battery lead</u>. If the insulation is compromised by vibration and/or pressure, short circuit to ground [point B in the diagram] could cause electrical overheating or fire

when not fused properly.

When the vehicle is stationary for an extended length of time, driving a temporary grounding rod and attaching the antenna ground to it will provide additional radiation to the otherwise limited abilities of the mobile antenna. In this situation, care must be taken to only operate on battery power so as to avoid a potential shock hazard from the permanent AC power grid.

Ground-loop Noise

Previously, we mentioned a phenomenon known as ***ground-loop*** noise. This is a very general term to denote noise generated within the grounding system and not the electrical or antenna-coax system. This type of noise is most often caused by a difference in potential between the station ground and the earth ground at either the antenna (in the case of a vertical) or the earth ground rod.

Several factors can cause this, not the least of which is using too small a wire gauge for grounding. Other causes may include having a earth ground for the antenna and a non-earth ground (cold water pipe for example) for the station. Ground-loop noise of this type tends to show up as unexplained 60 Hz noise on your transmitted signal or in the station audio on receive. Some operators have even reported noise on the transmitted audio or “birdies” and “hash” in the receive audio.

Because ground-loop noise can be difficult to identify, it can also be difficult to eliminate. Following the good engineering practice outlined in the text above, this type of problem is scarce indeed. One should reach the conclusion of ground-loop interference only after taking the steps outlined and all other sources of possible interference have been eliminated.

Next Time: Beams and Directional Antennas