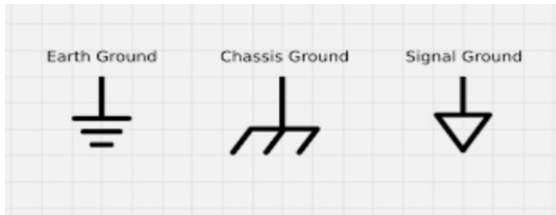
Station Grounding and Bonding

Question: What is a ground connection?
Answer: "It depends"



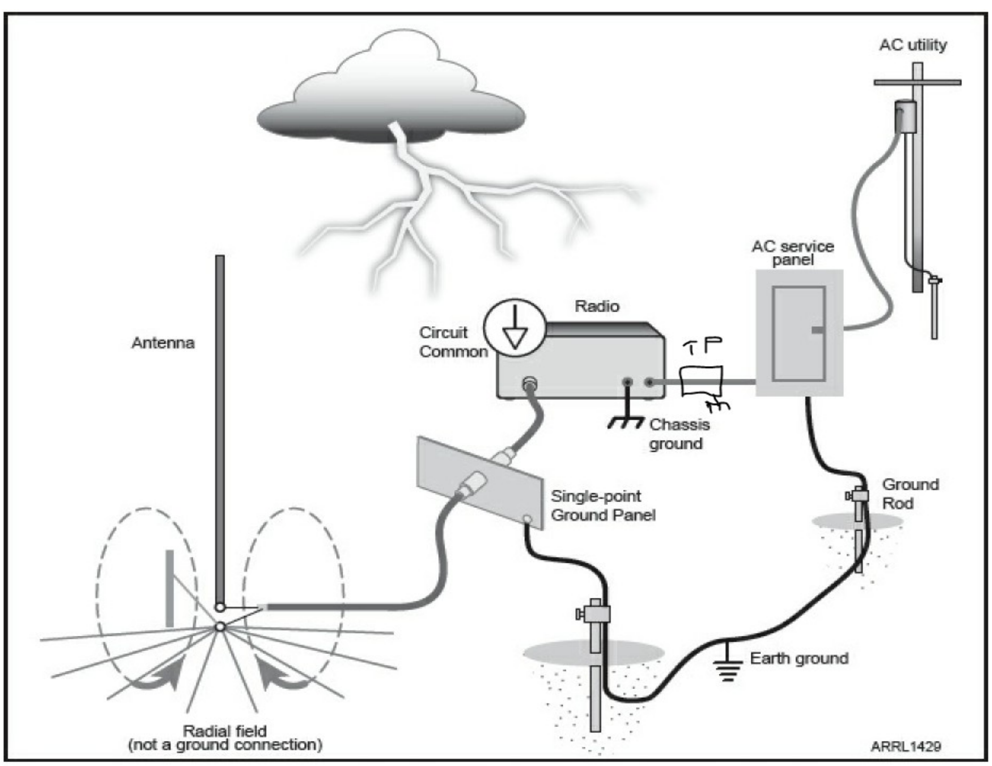
1. To the electrician, "ground" connections in your residence are a way of mitigating against ac shock hazards and short circuits in equipment. UL/ETL/IEC/NEC

2. In the ac power grid, the utility uses "ground" connections along the power lines to stabilize voltage in the ac power system. This is done for lightning safety and when a fault or power system imbalance occurs.

3. Ground rods outside your residence and the connections between them help minimize the damage a lightning stroke can do in your house or station.

4. To an antenna system builder, the term "ground" might refer to a "counterpoise" that gives RF current a path back to the feed point without flowing in the soil.

5. Circuit designers and station builders refer to "ground" as a common reference voltage — there are three different schematic symbols for these connections!

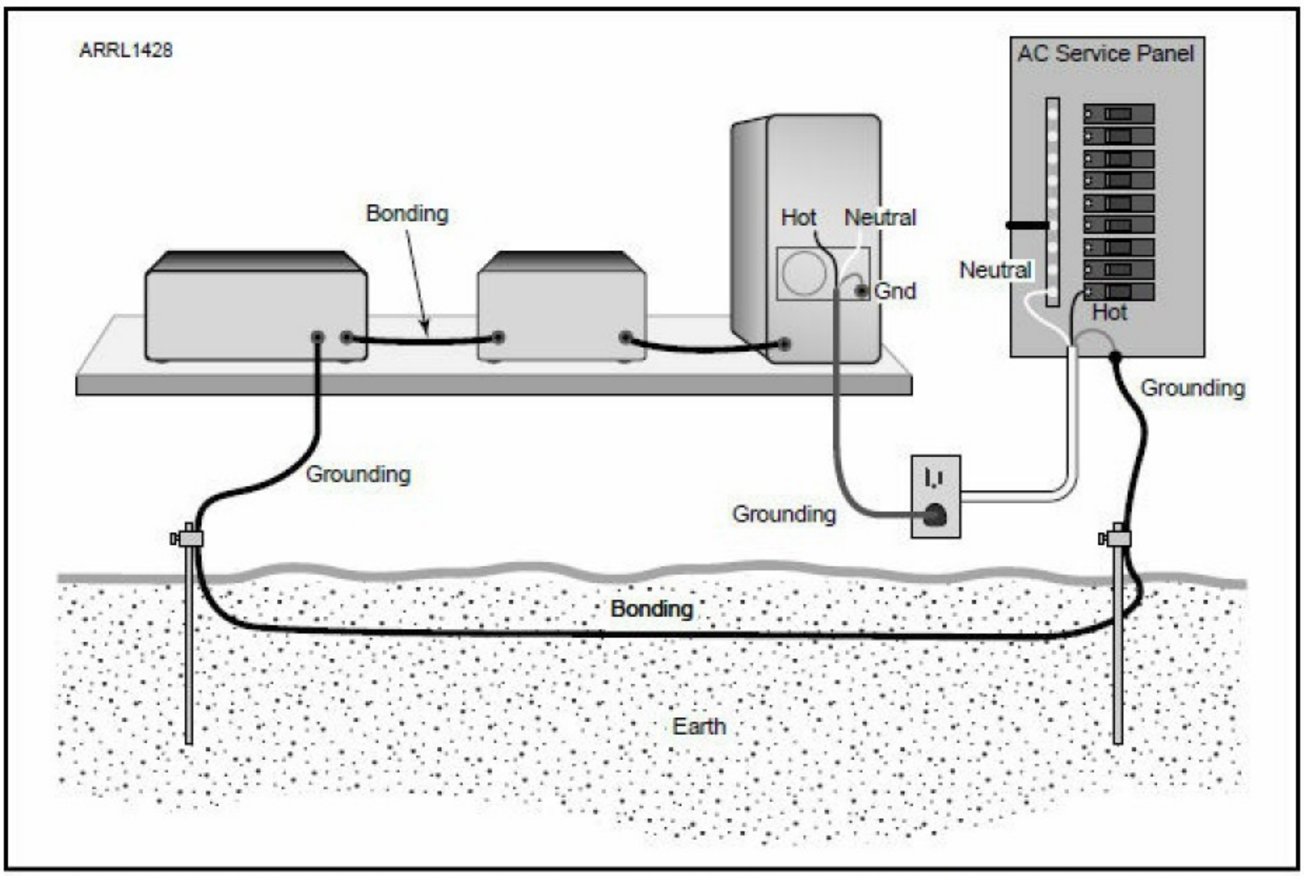


Why Are Grounding and Bonding Important?

• *AC safety*: protect against shock hazards from ac-powered equipment by providing a safe path for current when a fault occurs in wiring or insulation.

• *Lightning/Transient protection*: keep all equipment at the same voltage during transients and surges from lightning and dissipate the lightning's charge in the Earth, routing it away from equipment.

• *RF management*: prevent unwanted RF currents and voltages from disrupting the normal functions of equipment (also known as RF interference or RFI).

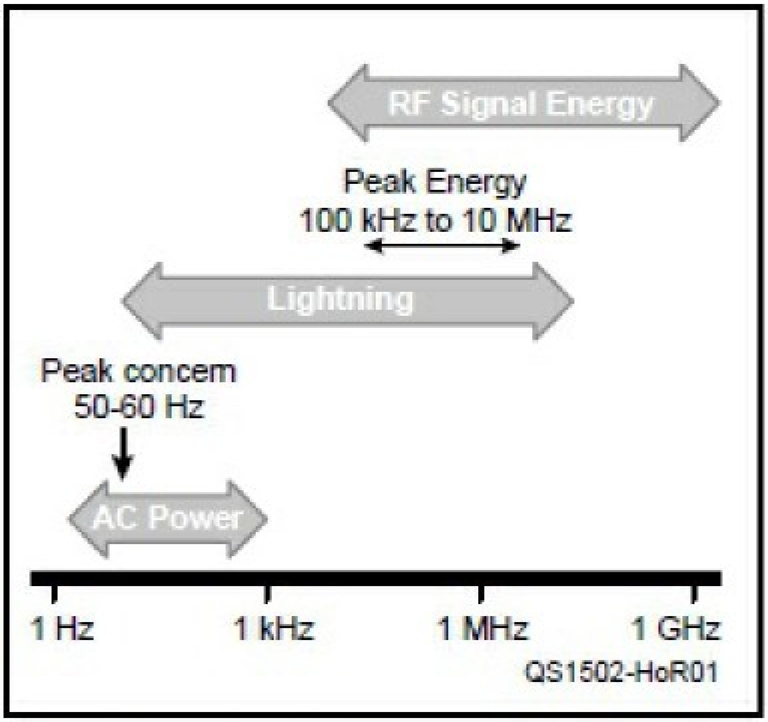


Grounding: **"A connection to the Earth"**

Bonding: **"To connect together"**

<u>Question:</u> What makes a good ground or bonding connection?

<u>Answer:</u> “It depends”

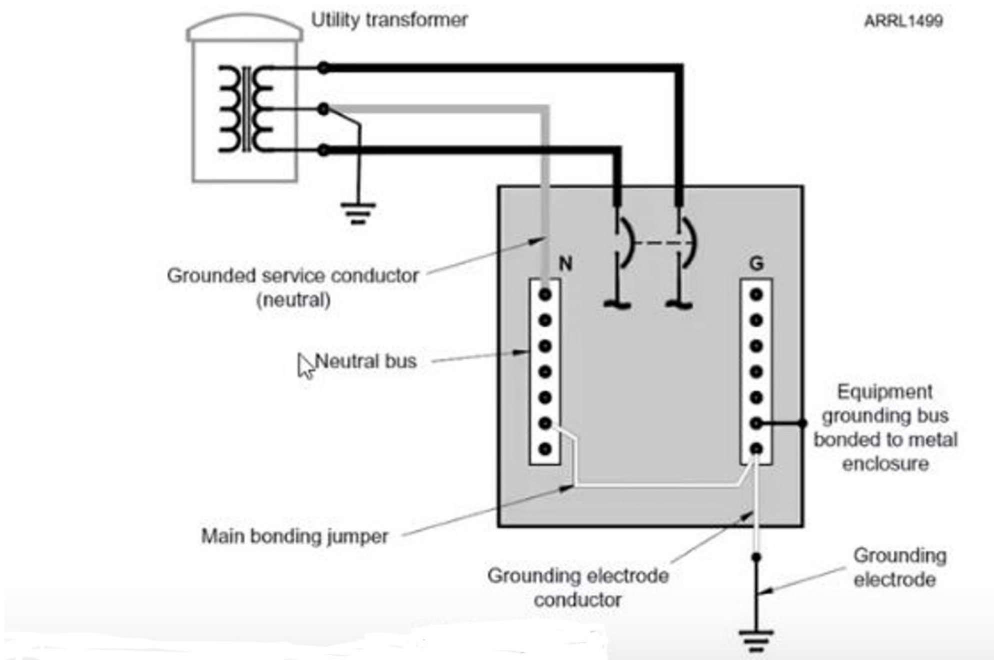


1. Low Z at frequency range of interest
Rule of thumb: Keep cable lengths less the 1/10 – 1/20 wavelength of highest frequency. Example: 10 Meters = 1.5 ft to 2 ft maximum. Use wide copper strapping or braid when possible.

2. Heavy enough to carry currents
Outdoors use 6AWG, Shack: 12AWG – 14 AWG

3. Robust enough to survive the environment
Outdoors: “Heavy cable” best. For earth ground bond, 6 AWG. Make sure rated cable, clamps are outdoor rated. For grounding straps, best to use solid copper strap rather then braid.

AC input Mains and Safety, a quick review



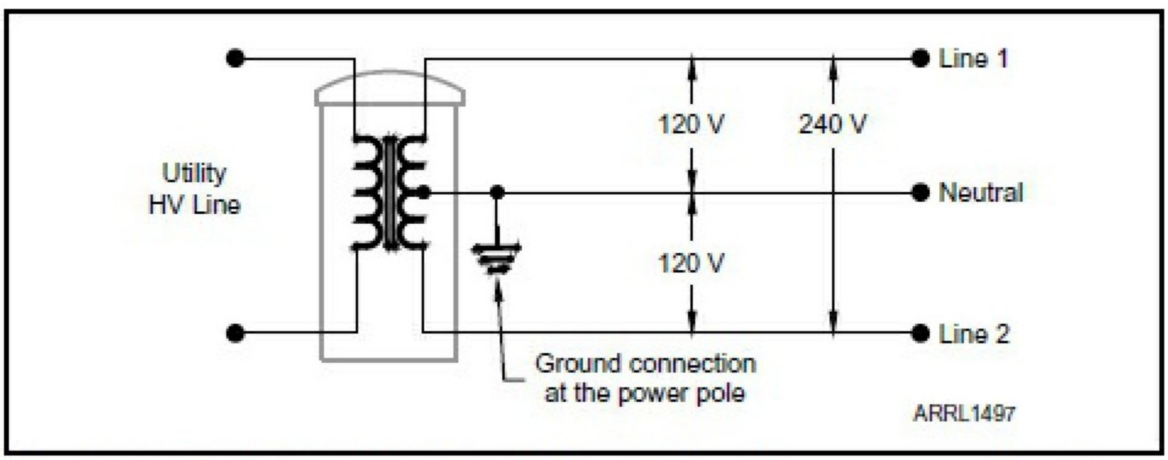


Figure 3.3 — Typical residential single-phase, three-wire ac power service. The electric meter is not shown.

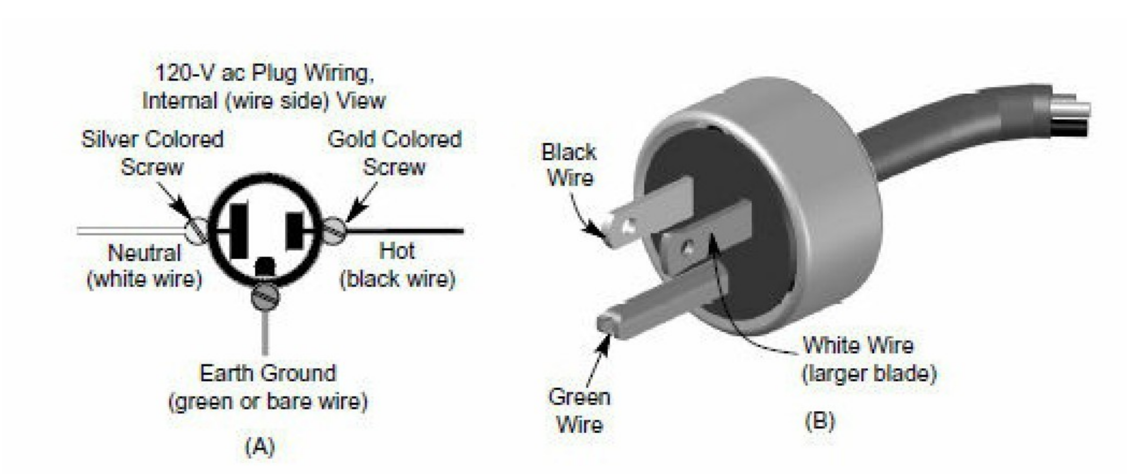
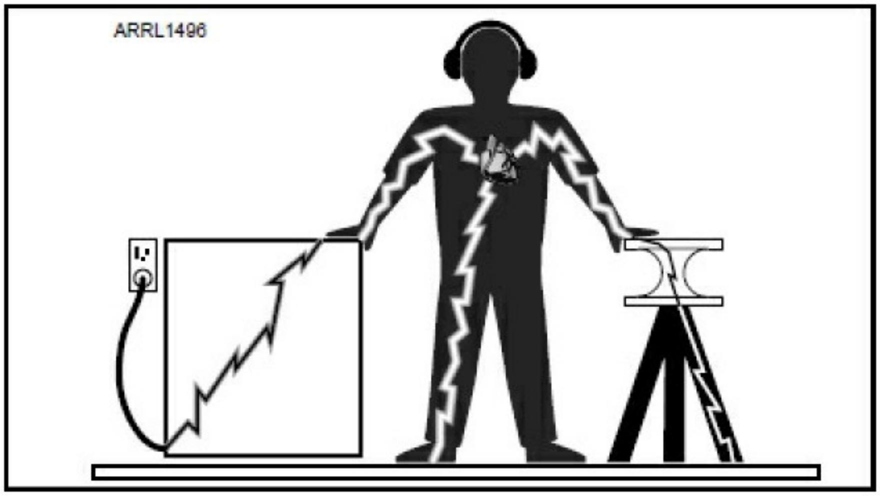


Figure 3.1 — The two most dangerous paths for shock current through the body are hand-to-hand and hand-to-foot because they go through the heart. This can disrupt the heart's electrical rhythm.



Keep one hand in a pocket or behind your back when making a measurement on energized equipment.

****Handheld meters and other instruments have a maximum voltage rating —** It is not the maximum voltage the meter can read. It is the **maximum voltage that can be measured safely!**

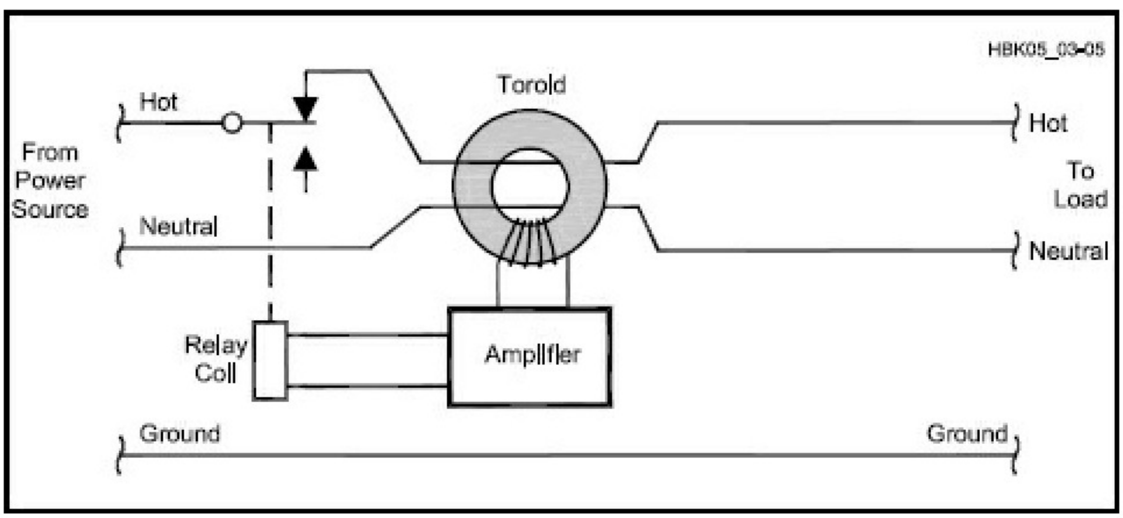
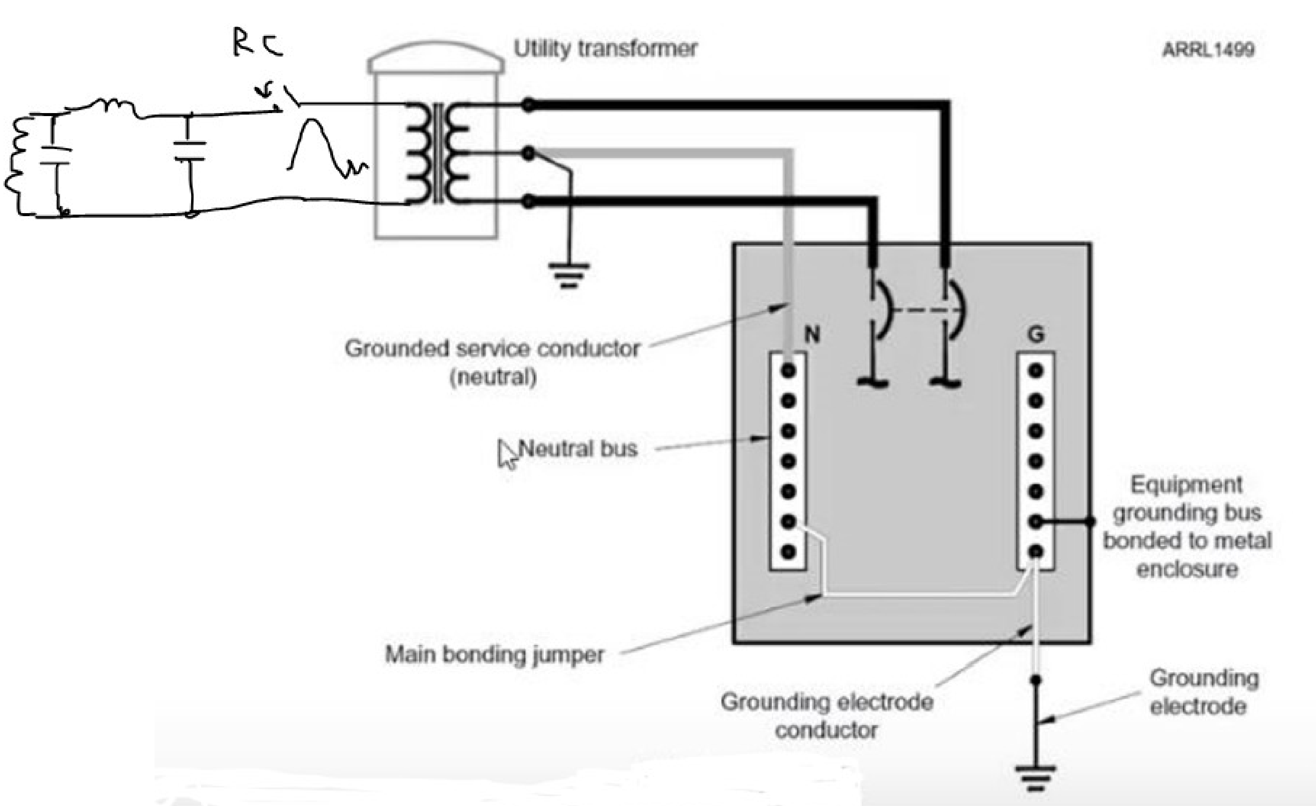


Figure 3.11 — Simplified diagram of a 120 V ac ground fault circuit interrupter (GFCI). Stray or leakage currents to ground unbalance the currents through the toroid which creates a signal detected by the amplifier. A relay then opens the hot conductor, de-energizing the circuit.

Lightning/Transients



****Transients from power lines down, trees on lines and reclosure operation occur much more frequently in the PNW than ligntning. A surge protected outlet strip ahead of your equipment whenever possible.**

**** Line filters can be used to further reduce power line coupled noise and switching transients**

Lightning as an electrical event

Peak current for the first pulse averages around 18 kA
(98% of the strikes fall between 3 kA to 140 kA at their peak). For the second and subsequent impulses, the current will be about half the initial peak. The typical interval between impulses is approximately 50 ms.

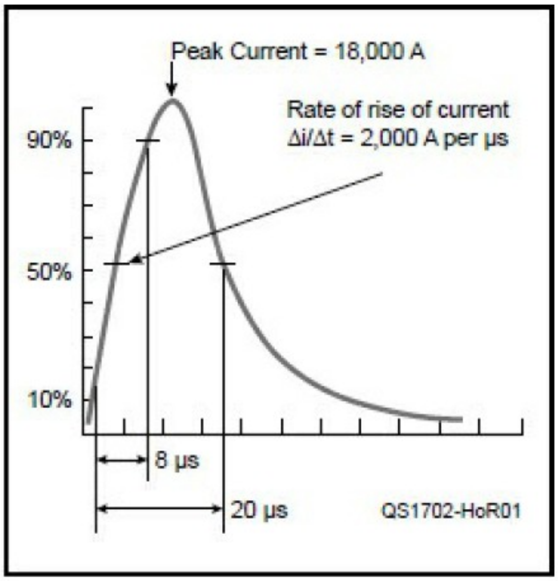


Figure 4.3 — The IEEE 8/20 model waveform for a typical lightning pulse.

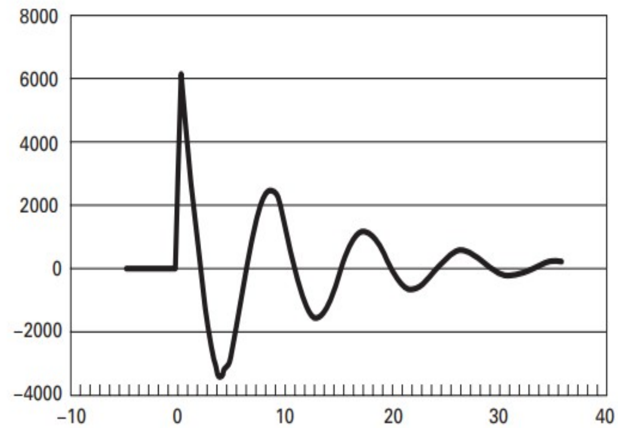


FIGURE 2. RINGWAVE

TABLE 2. IEEE C62.41 CURRENT/VOLTAGE WAVEFORMS FOR VARIOUS EXPOSURE LOCATIONS

CAT.	LEVEL	VOLTAGE (KV)	0.5μs X 100 KHZ RING WAVE CURRENT (A)	1.2 X 5μs (V) 8 X 20μs (A) COMBINATION WAVE CURRENT (KA)
A1	Low	2	70	—
A2	Medium	3	130	—
A3	High	6	200	—
B1	Low	2	170	1
B2	Medium	4	330	2
B3	High	6	500	3
C1	Low	6	—	3
C2	Medium	10	—	5
C3	High	20	—	10

****Lighting induced voltage across a wire: $V = (I \times R) + (L \times \Delta i/\Delta t)$**

<u>NOW THE GOOD NEWS for the PNW:</u>

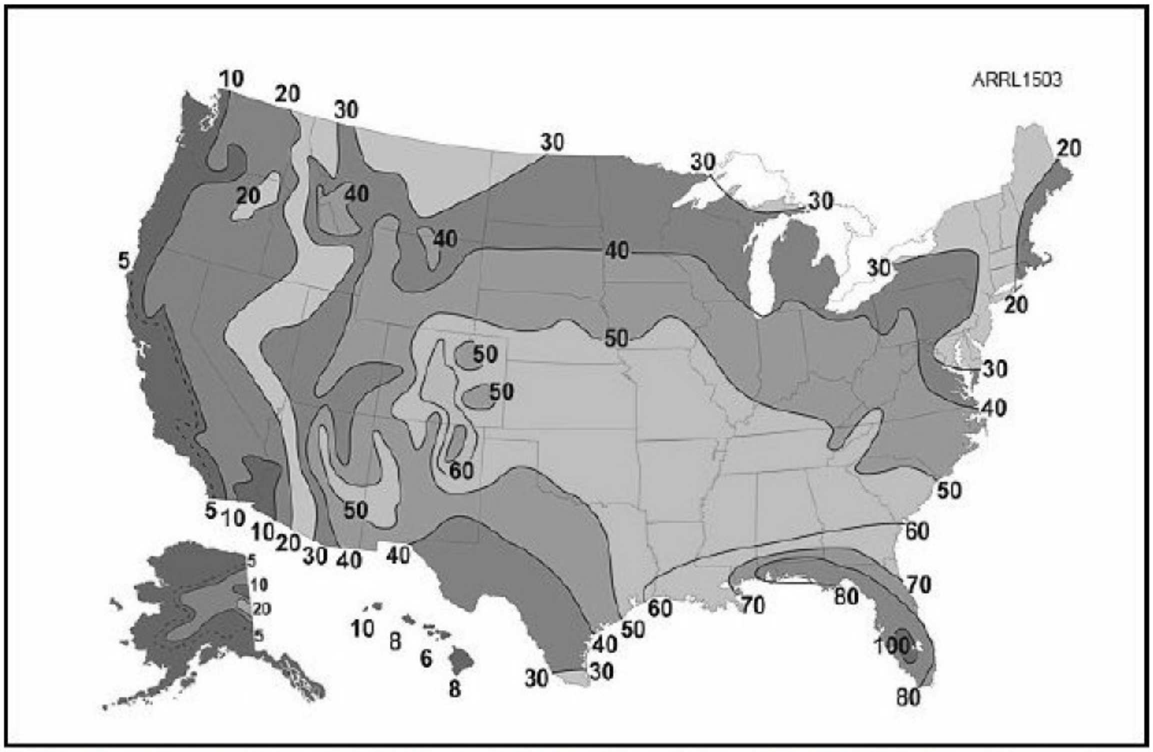


Figure 4.1 — Average number of thunderstorm days each year throughout the U.S. The most frequent occurrence is in the southeastern states, with Florida having the highest total (80 to 100+ days per year). [Map courtesy of NOAA]

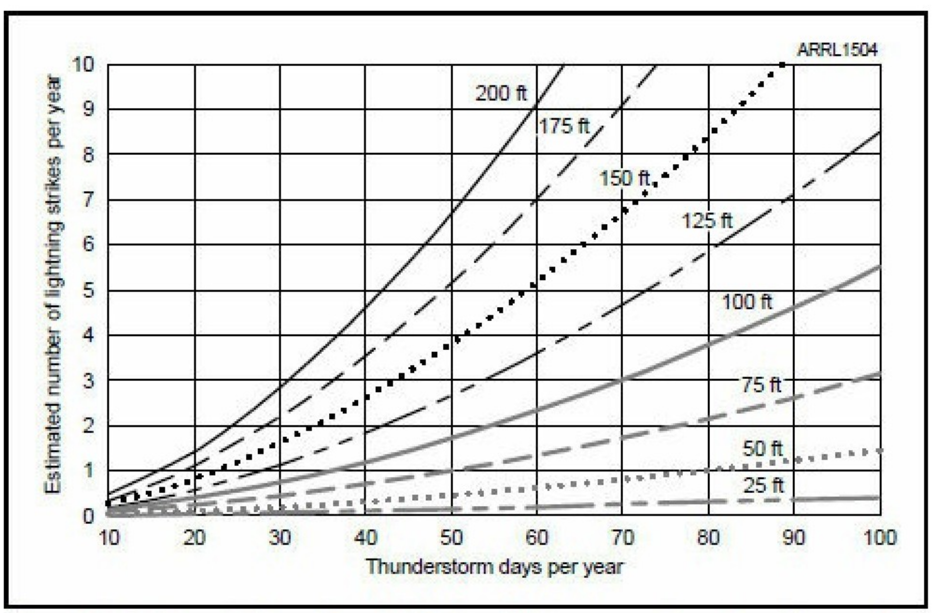


Figure4.2 — Estimated number of lightning strikes per year based on the number of thunderstorm days in your area from Figure 4.1 and the height of your antenna or tower. [Based on information from *Living with Lightning*, Seminar Notes #ECP-826B Version F, GE Mobile Radio Technical Training, © GE 1985]

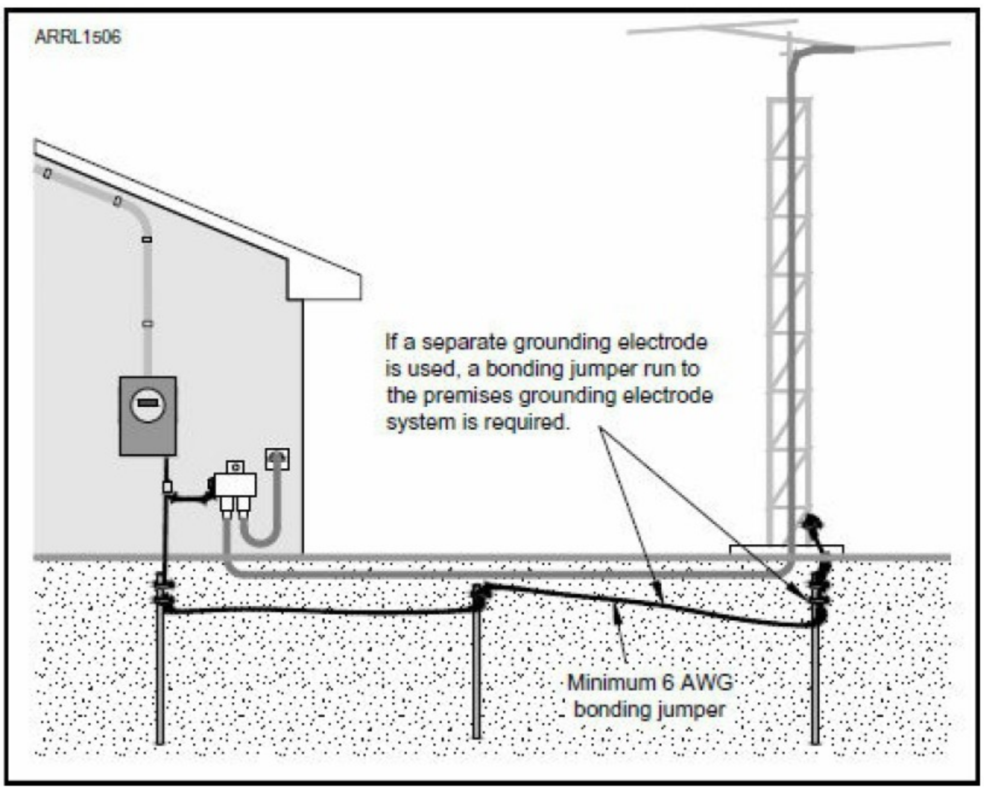
Controlling Current Paths: Perimeter Grounds

*The primary purpose of the external ground system is to disperse as much of the lightning energy as possible into the Earth so that less of it follows the feed line into the radio station.

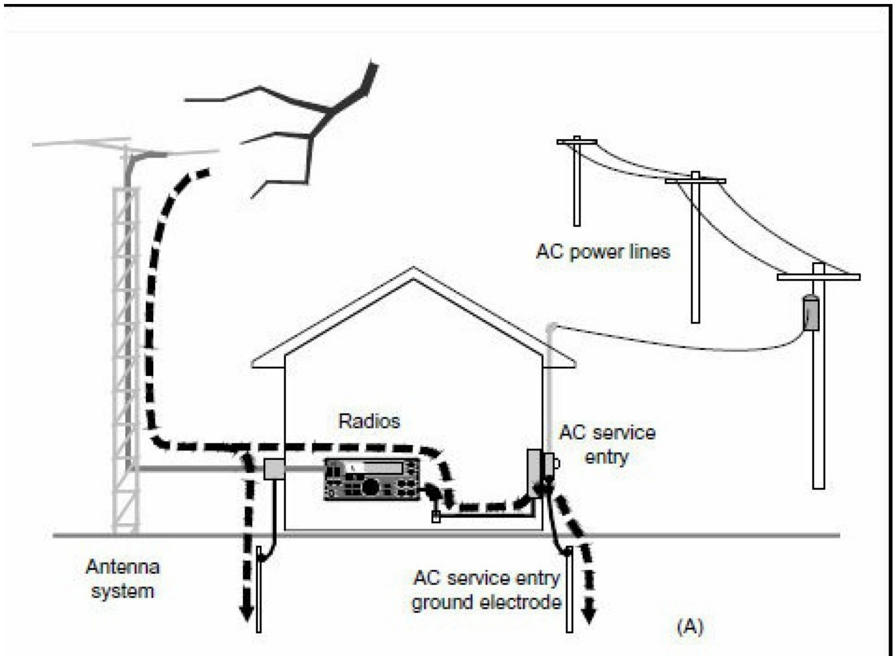
*Grounding methods for safety and lightning protection compliment each other!

**The safe path for current in the ac safety ground is back to the common connection between the power system neutral and the ground conductor.
**The safe path for current in the lightning protection system is away from your equipment to the ground electrode and then into the Earth.
**As long as all of the ground electrodes of these two systems are bonded together, they do not interfere with each other and can even provide additional safe current paths.

Figure 4.5 — The bonding jumper between an antenna system ground electrode and a building's ground system must be at least #6 AWG. [Courtesy Mike Holt Enterprises of Leesburg, Inc.]



No Ground Rod Bonding:



With Ground Rod Bonding:

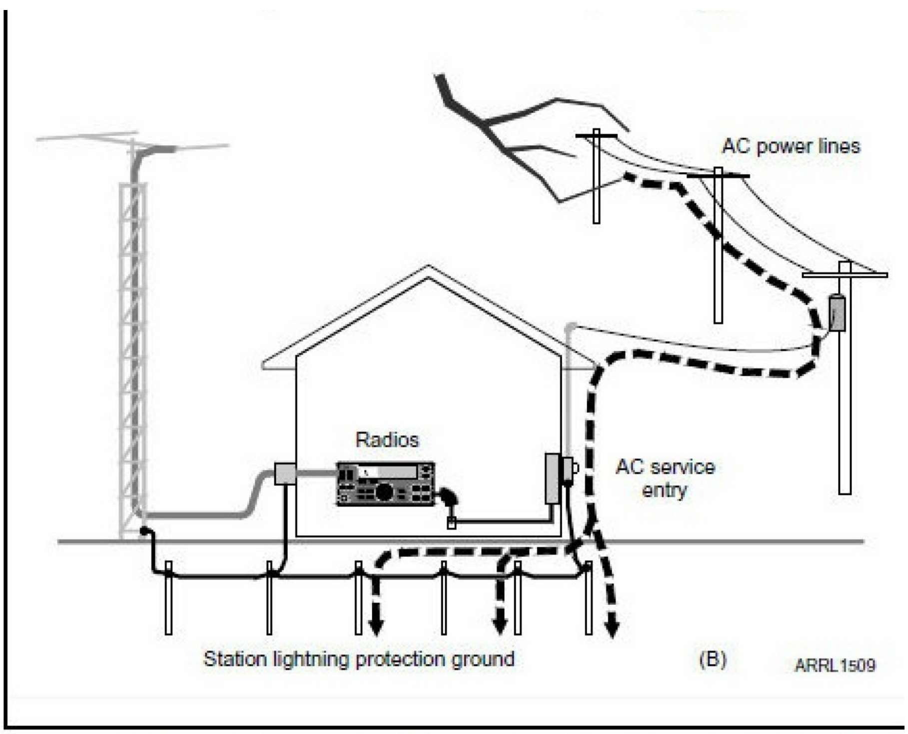


Figure 4.14 — At A, without a perimeter ground, lightning striking the power line or tower will take paths through the building to reach additional ground electrodes. A perimeter ground has been added at B, providing low-impedance paths to the Earth, minimizing lightning energy in the station and home.

Ideally, the connection to a ground rod should be made using an exothermic bonding process. (This is considered a “welded” connection and the technique is often referred to as “one-shot welding.”) See Erico Incorporated (www.erico.com) and Alltec Corporation (www.allteccorp.com).

www.youtube.com/watch?v=T5DoB26TFtI

A brief mention of Towers

*Each coaxial cable traversing your tower should be properly bonded to the tower

*Tower as an insulated driven element: Use spark gaps

*For towers taller than 150 feet, bonding should be done every 75 feet down the tower as measured from the top.

Figure 4.16 — A commercial coaxial cable grounding kit from DX Engineering (A). The same kit used to bond a pair of coaxial cables to a tower leg (B).

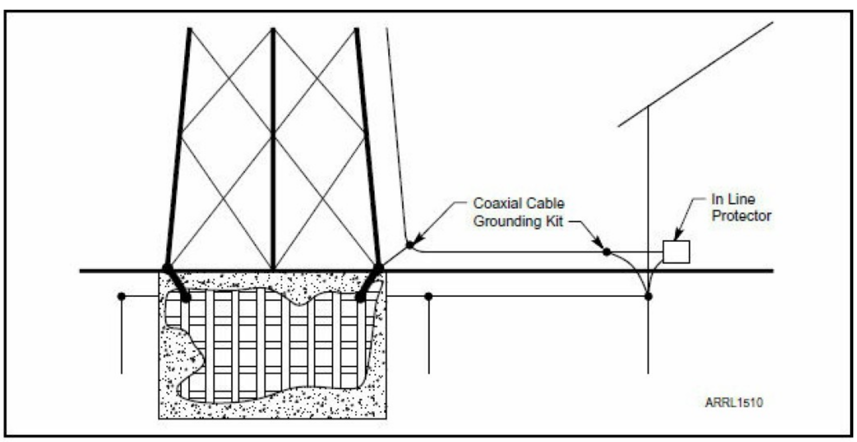


Figure 4.15 — Grounding coaxial cables should be done at both the tower top and the base as well as at the entry point to the house or building. For minimum energy transfer from the tower, bring the coax all the way down the tower and use a cable shield grounding kit. [Drawing from *The "Grounds" for Lightning and EMP Protection*, Roger R. Block, PolyPhaser Corporation, Minden, Nevada]

Single-Point Ground Panel (SPGP)

One of the most important parts of the lightning protection system is the *single-point ground panel* (*SPGP*). This is the point at which all antenna system feed lines, equipment power, and control lines are brought together to share a common ground connection.

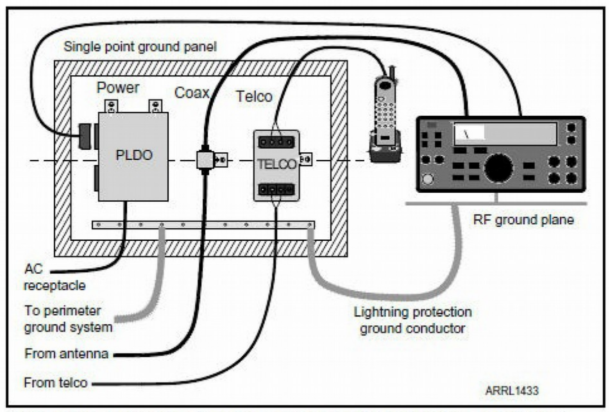


Figure 4.17 — A drawing of a single-point ground panel (SPGP) showing how various lightning protectors are mounted. The protected side of the panel is at the top in this drawing. Cables above the dashed line are protected and below are unprotected.

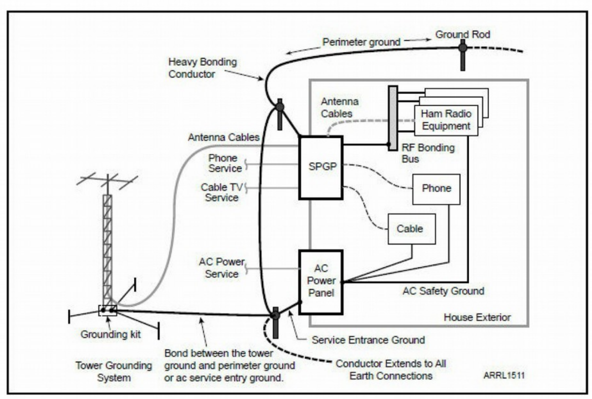
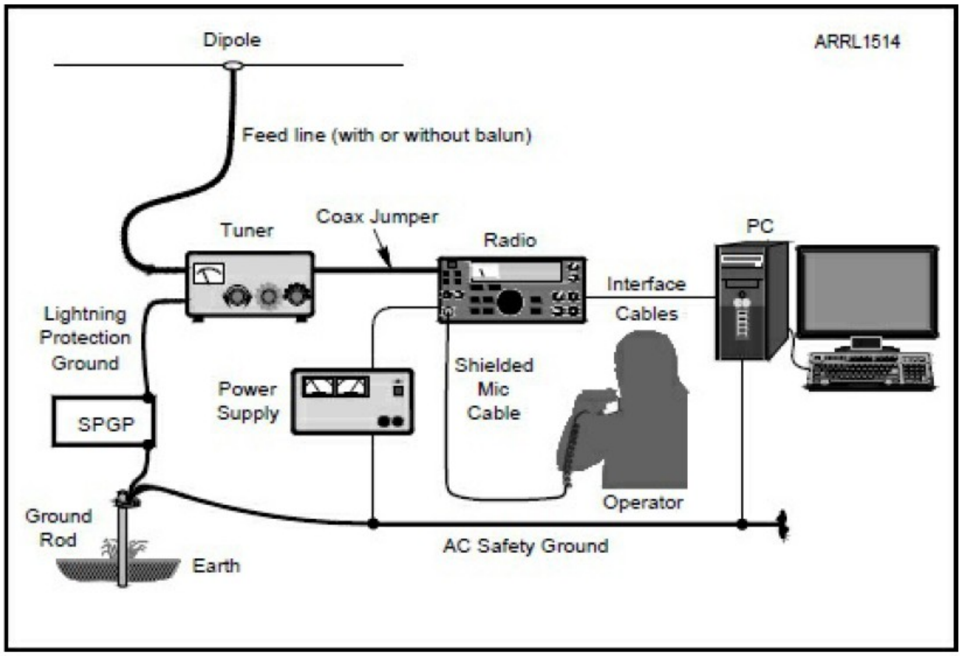


Figure 4.18 — Overview of a building lightning protection system with an SPGP. All services that cross the building perimeter are protected by either the SPGP or the ac service entry ground connection. All ground electrodes are bonded together as well. Note that this drawing does not address protection on internal circuits from induced voltages and currents.

RF Management

Figure 5.1 — The complete antenna system for a typical basic station. Everything conductive, including the operator holding the microphone, is part of the antenna system.



Common and Differential Mode currents

** Differential-mode current is a pair of currents with the same amplitudes but flowing in parallel and opposite directions, independent of any return path, such as a ground connection.

** Common-mode currents flow on all conductors of the line in then same direction with the same value.

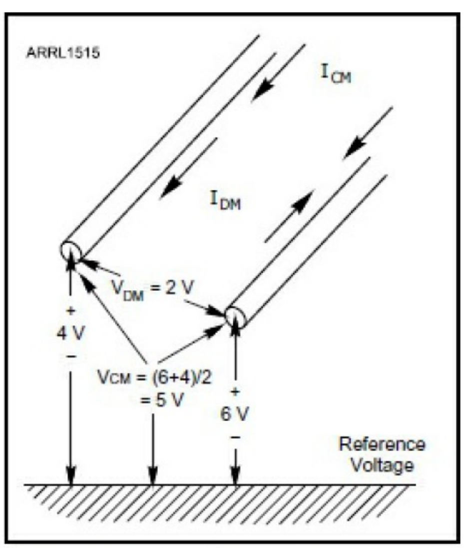


Figure 5.2 — Differential mode and common mode voltages are illustrated as V_{DM} and V_{CM}. Differential-mode currents, I_{DM}, flow in opposite directions, while common-mode currents, I_{CM}, flow in the same direction on both conductors.

****In the shack RF "hot spots" in the near field can exist due to antenna feedline common mode radiated RF, ground wire coupling, ground loop radiated RF, transmitter output leakage and antenna radiation.**

**For example, if the station is operating on 10 meters, at least one potential hot spot is never more than about 8 feet away. Peaks are ½-wavelength apart and so are the nulls, with peaks and nulls offset ¼-wavelength apart.

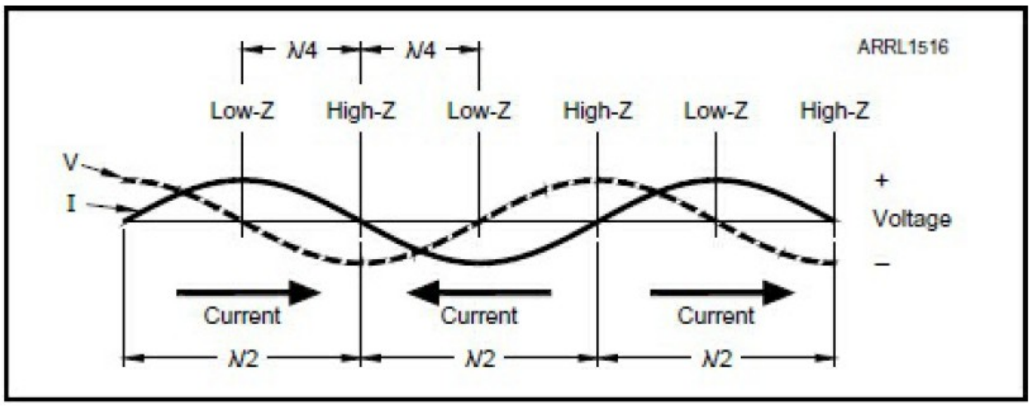


Figure 5.3 — A resonant conductor 3λ/2 wavelengths long with a typical pattern of voltage and current peaks. Peaks of either voltage or current are λ/2 apart and there is λ/4 between a voltage and current peak (or null).

<u>These localized "hot spots" cause voltage differentials to be created between equipment chassis ground references and cables.</u>

Some issues that can occur are:

1. USB peripheral lockup or operation (keyboard, mouse, external hard drive)
2. PC lockup requiring reboot
3. Audio interface noise
4. Remote rig control issues (serial port)
5. Output power/ALC instability

Bonding to Equalize Audio and RF Voltage

**The most important step in reducing audio noise and managing RF is equalizing audio and RF voltages throughout your station as much as possible.

**By bonding equipment together to make the voltage difference as small as possible, current flow between the equipment is also minimized.

**A comprehensive bonding effort pays benefits at all frequencies.

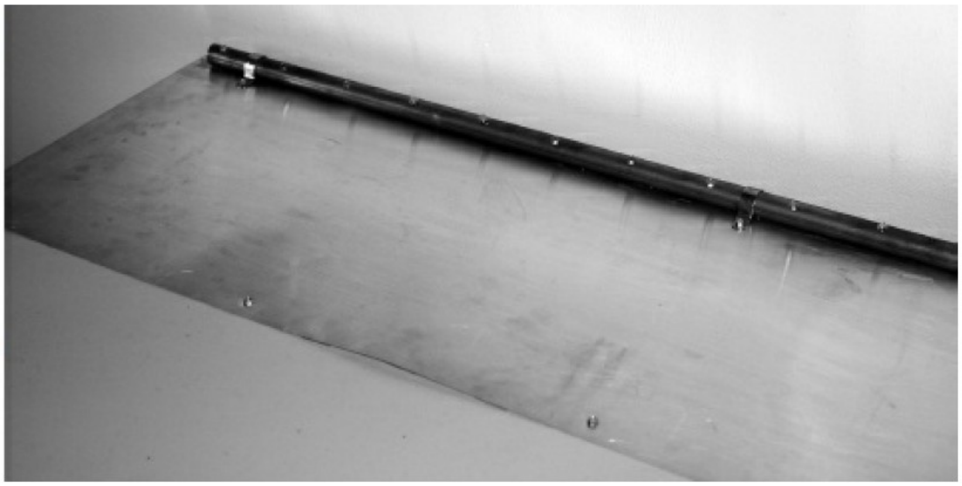


Figure 5.5 — An RF ground plane made of aluminum flashing is attached directly to a plastic table top with self-tapping screws. An RF bonding bus made of copper pipe is attached to the flashing with pipe clamps. Sheet metal screws in the pipe are available for bonding jumpers to be attached.

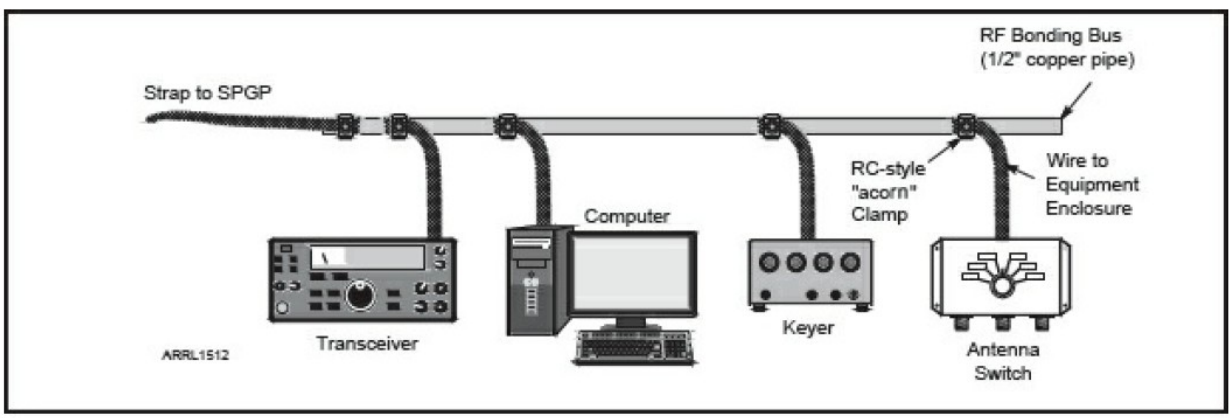


Figure 4.19 — A typical bonding bus for a station with all equipment on one table or desk. Connections to the equipment should be made with heavy wire (#14 AWG is suitable) or strap, using properly listed clamps or screws. According to the NEC, ground jumpers should curve toward the bonding bus in the direction of the ground connection although this is not practical in many amateur stations. See the chapter on good practice guidelines for a better discussion of a bonding bus and the associated connections.

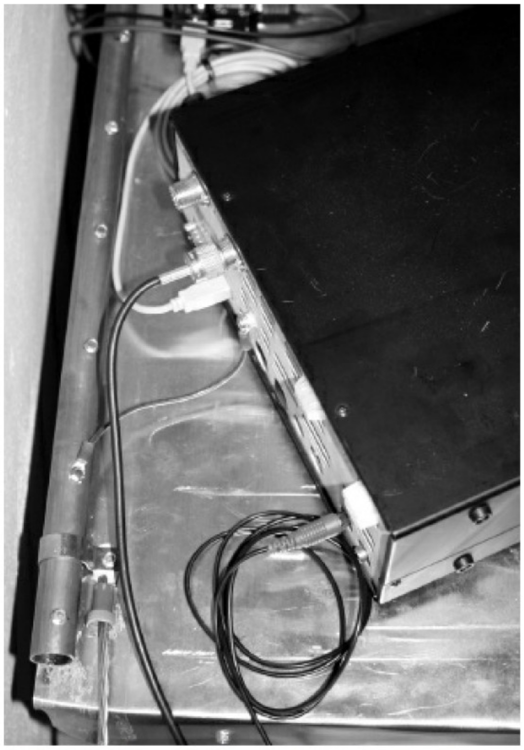


Figure 5.6 — Coiling up extra cable length and laying the cable directly on an RF ground plane minimizes the amount of RF picked up by the cable.

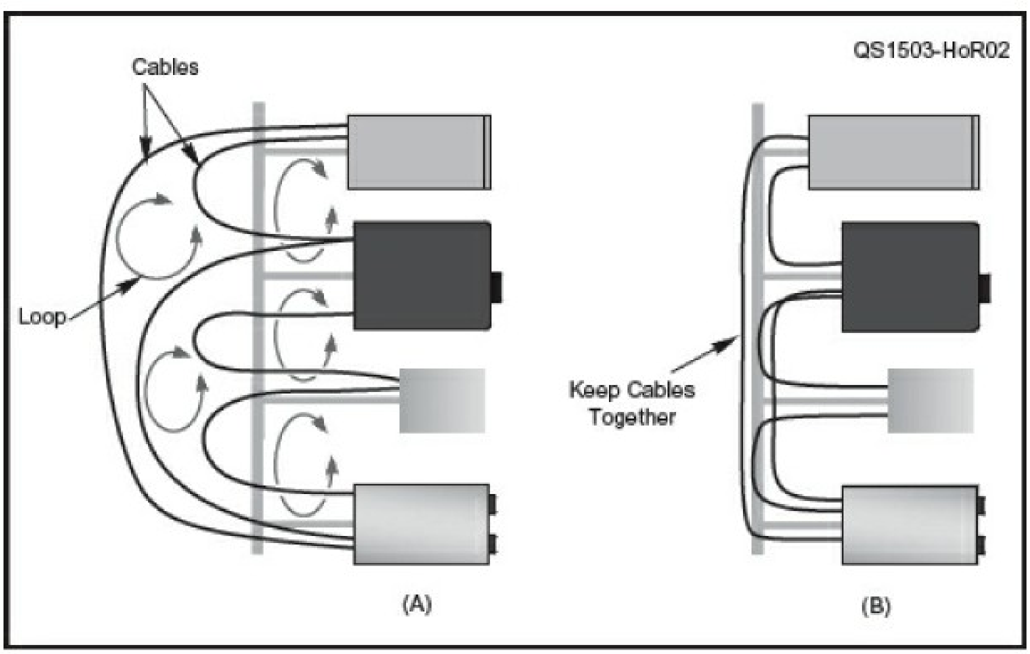


Figure 5.8 — Each conductive path through enclosures and cables creates a loop (A) that can pick up and radiate signals. Minimizing cable length and loop area by keeping cables together as at (B) can reduce RF pickup.

Solid copper strap (A) is the recommended material for grounding and bonding connection at RF. Flat-weave tinned braid (B) can be used if protected from water and corrosive gases or liquids. [Photos courtesy DX Engineering]