Practical, Economical, Good GROUNDing

11/2007

"A good ground is one of the most essential parts of a solid HAM station." There are various reasons for this statement. First and foremost is for the safety of your family, home, and HAM equipment. Lightening **NOT ONLY KILLS radios** but can start house fires! A protruding antenna or tower into the atmosphere dramatically increases your odds of a lightening strike. Statistically however, most lightening damage comes from the AC power and telephone lines running into your home.

An understated fact of significance to HAM Radio is that **a good ground WILL increase receiver sensitivity** and transmit propagation. I've, personally, observed a decrease in surrounding ambient noise levels, from as much as S9 to S4 drop, on 75/40 meters when I shifted from a "cold water iron pipe 12 AWG wire ground" to a RF ground system stated in this paper. HF antenna(s) work BEST when they work against a "proper" counter-poise ground reference.

RF grounding is as mis-understood and as difficult to understand as "impedance." Both are very real, hard to measure, and cannot tangibly be seen in operation. The term that is used in RF grounding is "***skin effect***." In a ground system the vast majority of electrons run along the "outer most surface or skin of the conductor. A good RF ground has the least amount of resistance to electrons being conducted to ground via the most amount of conducting ***surface area (skin)*** that is practical. The goal of a good RF ground system is to obtain as "little" resistance as possible between the "antenna/tower-to-ground" and the "radio-to-ground". Thus the more conductive ***surface area*** the larger the path for electrons to earth ground. You could argue that multi-stranded cable/wires have more overall wire surface area but the touch areas of the wires negated skin effect conductance. **Do not confuse current carrying capability with grounding skin affect** they are two very different elements of electrical conductivity.

A typical laboratory/aerospace test system ground measures <12Ω from "Unit-Under-Test to earth ground". A very very GOOD cold water iron pipe ground may measure as little as 35Ω and that's if the water pipes are NOT PVC. [BEWARE – most new home construction use PVC pipes for water and sewage. Even in older homes the water service provider should have installed ≥5' section of plastic pipe between the water mains and your home water line feeder – this is to eliminate electrolysis/galvanic action within the piping system.]

Making a ground measurement is very difficult and most HAM's do not have a Megger™ generator type instrument to conduct a valid resistance measurement. This paper will attempt to "assist" in providing knowledge and examples of "reasonably good" RF ground systems that are within the economical range of most HAM's and that can achieve <20Ω. How good a ground system you want installed is directly proportional to the amount of effort and funds you want to invest in the safety/operation of your station.

Disclaimer: Will installing these grounding methods written here prevent a loss of equipment from a lightening hit, ***NO!*** *What it will do is help in minimizing damages.* ***Are the methods in this paper the "best"? This is a loaded question that few understand but all HAMs seem to be experts on.*** *When getting into these philosophical arguments I resign myself to just listen to what these self proclaimed experts profess and either improve my knowledge or shake my head in despair and walk away – you cannot improve self-proclaimed experts knowledge. PolyPhaser™ has a much more elaborate ground system plans but I cannot afford nor do I have the acreage to install a PolyPhaser ground system (designed for the infinite budget commercial world).*

You need to answer the following questions before installing your RF ground system:

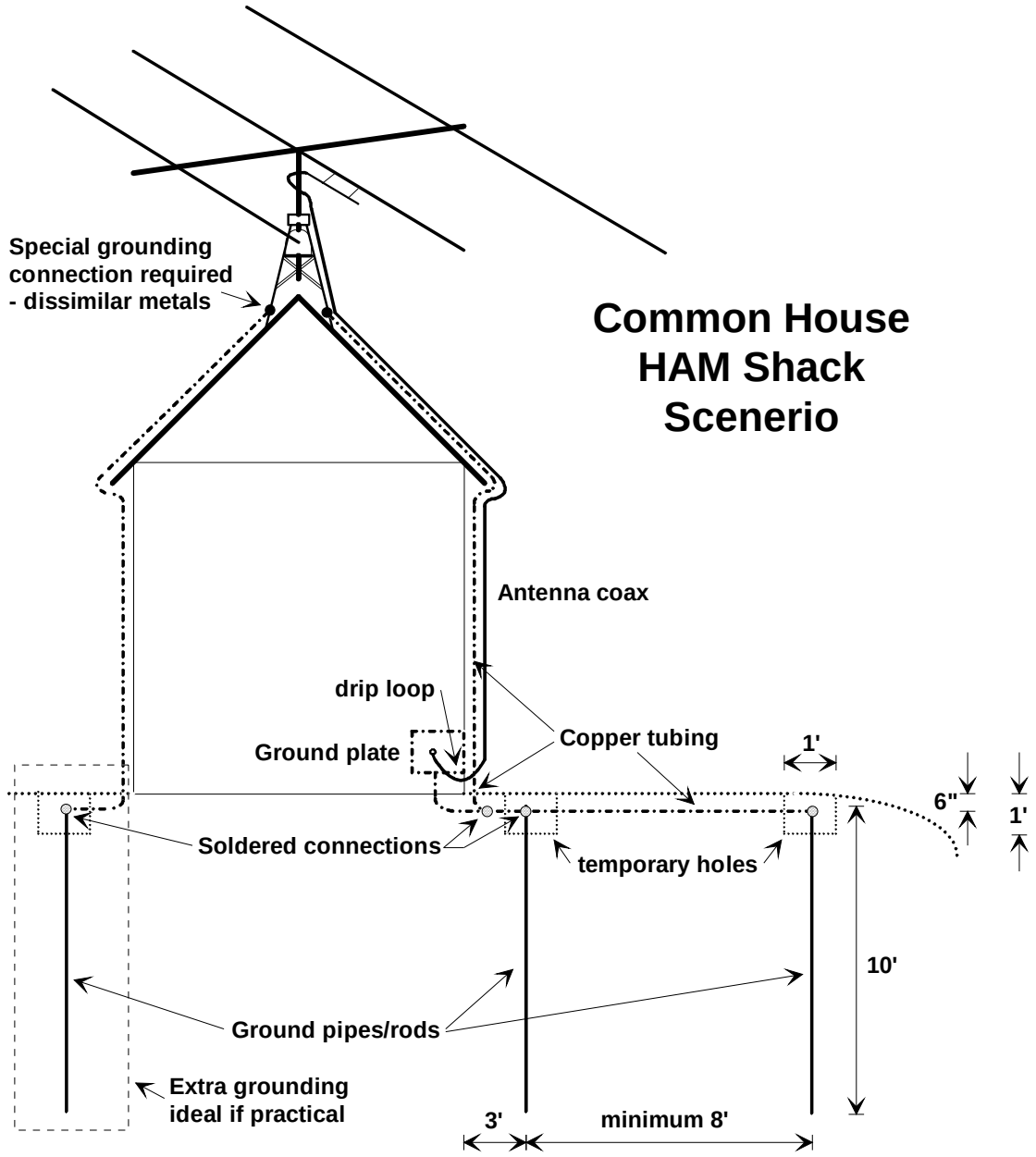
a. What are you willing to spend?
b. What amount of effort are you willing to give in installing a ground system? It is **NOT** to your advantage to be too cheap or lazy - or you might as well just use the cold water pipe. Then get HAM insurance as eventually you will be buying new equipment when lightning strikes or you get a near strike (and maybe rebuilding your home too).
c. The type of soil where you are planning to install the ground system. I'll address this later in the paper.

A few installation RULES:

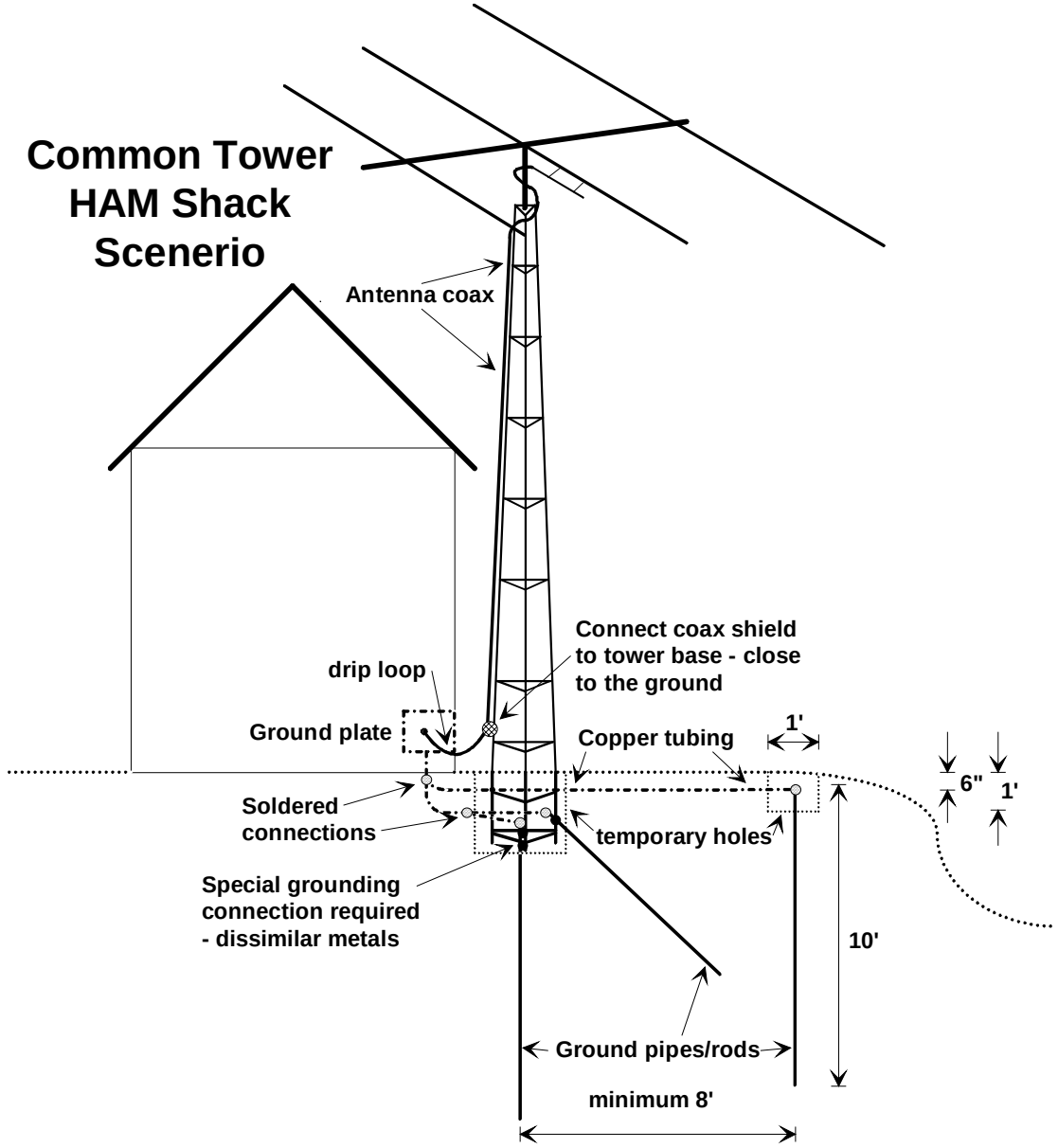
1. Dissimilar metals (as it pertains to electrolysis/galvanic action) pose a significant problem to the longevity of the ground system and how much annual maintenance you will need to do to maintain your ground system. **NEVER** connect copper to galvanized metal (towers) or aluminum - use a stainless steal interface between these two metals using stainless steal hardware!
2. Copper oxide (the greenish copper corrosion) is **NOT** conductive! Eventually, compression clamps WILL allow corrosion to migrate into joints causing a reduction in conductivity increasing the system overall resistance. Weld, braze, or solder ALL joints (when possible) this will ensure long life and maintain stable good conductivity between connections!
3. If stainless steal clamps/hardware are used apply a liberal amount of conductive grease (like Penetrox™). This grease will minimize connection moisture degradation due to corrosion – but if this connection is in the open environment you need to inspect these joints annual to insure these areas have not been washed out by rain or melting snow.
4. Eliminate ground loops and multi-point ground connections when possible. A HAM shack ground loop gives lightening another path to your equipment**. Always use a single point ground between the interior and exterior of your HAM shack!**
5. Run your coax/hard-lines to the base of your tower or antenna mast and THEN make the run into the house. This does two critical functions; allows lightning to get as close to the actual ground before attempting to enter the building – often lightening will jump to the actual ground rather than enter the house. And it creates a drip bend in coax/hard-line to keep the rain out of your house – mitigating dry rot potentials
6. Coax/hard-line bends should use a minimum radius of nine inches for any bends.
7. If possible directly connect the coax/hard-line shield clamps to the tower/mast base.
8. Grounds rods or other grounding pipes **MUST** reach below your local areas permafrost layer to remain active year around. You can easily find this level by checking your local plumbing building codes. [Typically, central Wisconsin is minimum depth of six feet, northern Wisconsin/Upper Michigan is ten feet, and central Ohio is three feet.]

This paper gives examples of two scenarios for a “good & reasonable” HAM ground system:

First a house mounted antenna ground system;



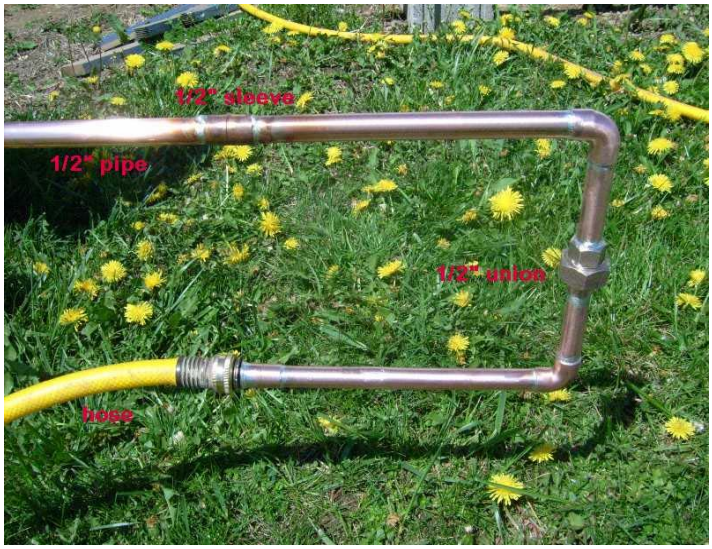
Second a tower mounted antenna ground system.



Grounding Rods vs. Pipes

A four foot rod is nearly worthless as they do not make enough soil contact to be an adequate safety ground much less an RF ground and they may not reach below the area frost line. Have you ever tried to pound an eight foot rod perpendicular into the ground to hit hard pack or rocks? Then try to pull out the rod to start over – no way. No mallet or "T" post sledge for me. I've taken another approach that is more economical and has increased soil contact surface area. I hydra-drill a ten foot section of ½" schedule K or L copper "PIPE" in lieu of a rod. The copper pipe has more contact surface area with the soil than any rod. Larger diameter copper pipe could be used but that small amount of increased surface are is not worth the exponential increase in costs/effort.

My Rube Goldberg hydra-drill hose connection is not a Wouff Hong or a Rettysnitch but could be used as one. This hose connection plumbing is a brass hose fitting soldered to ½" pipe, elbows, and union that is soldered to the top of the copper pipe. This design came from my school of hard-knocks; my first attempt I put the hose fitting in-line on the end of the 10 foot pipe but the hose did a 180° pinching the hose stopping the water flow. Plumbing dimensions are not critical. With the addition of the union I can turn the hose to any angle insuring full pressure flow is maintained.



I dug a one foot cube deep hole into the ground where the ground pipe is drilled about 5' to 10' from the house. (Beware of drilling within 3' of the house foundation especially if you have a basement, contactors put all types of rocks/gravel around the house foundation to fill in the gap and provide drainage to the basement perimeter curtain drain.) I dug a 6" deep trench between the hole and the house where you intend to have the ground system enter the house. This allows me to bury the whole ground assembly making it invisible to all and my lawn mower.

I drilled the pipe into the ground until the pipe top was ~6" below the surface of the ground. I used two Vice-Grip's™ pliers as handles onto the copper pipe. I work the pipe up and down allowing the water to flush the soil and small gravel from the pipe tip. If you hit a rock – pull it out and change the attack angle slightly and re-drill. The feature of hydra-drilling is if you need to pull out the pipe the water pressure will help you and keep the hole lubricated – easy work.

Ground Conductor Copper Buss-bar vs. soft Copper Tubing

Due to the economics and availability of copper buss-bar material I found the costs to be prohibitive to a normal HAM's budget. Instead I use soft copper tubing that is easily obtained at your local hardware store. The trade off is the amount of surface area the copper tubing will have in comparison to copper buss-bars. I highly recommend that you use ≥½" copper tubing for short runs, i.e. ≤15', or as your budget will allow. The larger the tubing diameter the more surface area the better the ground conductivity!!!

I use soft copper tubing for practical reasons and the ease of use. I hammer the soft tubing flat where it will make contact to the copper pipe. Using Vice-Grips™ I wrap the flattened 6" of tubing very tight around the copper ground pipe to make a good soldered connection. After soldering I go one step further and drill a hole though the soldered soft pipe and rigid copper pipe to install a #10 stainless steel bolt and nylon-lock nut. This gives me an added confidence that the joint will never come undone due to strain, stress, or lightening heat.

The soft copper tubing is buried at least 6" deep. This will keep you from hitting the ground system with the lawn mower or becoming a trip hazard. The buried copper tubing will also add to your energy dissipating ground system. Burying the bare copper tubing insures maximum "ground system" conductivity is obtained with an additional benefit by watering your lawn you will increase near surface soil conductivity - a HINT during contesting.

Ground Plate

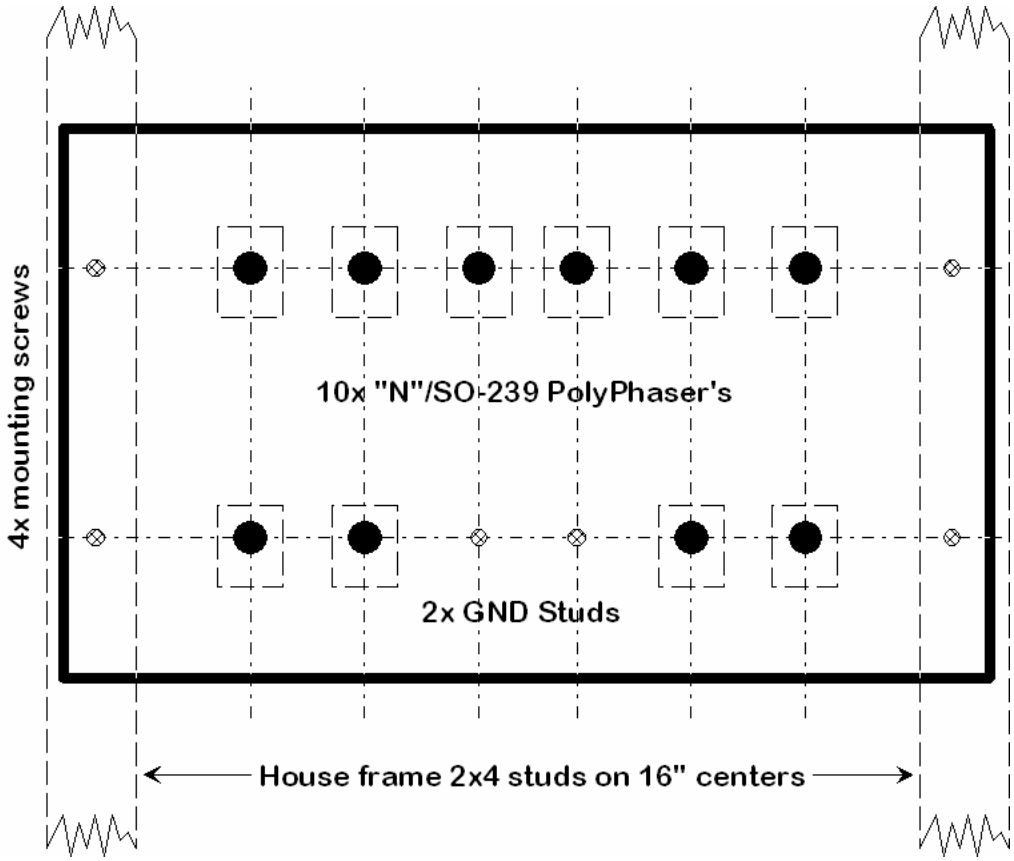
This can be controversial as few HAMs want to mount or put a fair sized hole in the side of their house. The ground plate is a solid metal ground barrier to keep lightening from entering your house. The ground plate is the fundamental item that creates your "***single point***" ground and gives you the proper place to install rotor cable protector, coax protectors, even telephone line and cable TV protectors, etc.

I recommend that the ground plate be made from ≥0.125" stainless steel or copper plate; the plate dimensions depend on how many protectors are needed to be mounted (oversize and plan ahead). I selected stainless steel as it eliminates the ***dissimilar metals*** concern and allows direct copper attachment. I had my plate cut to reach from house stud to stud (16" centers) for good solid mounting – some silicone sealing compound and the bugs/moisture stay out!

I label all my ground plate feed-thru connectors and use the plate as my RF patch panel. If I get a real intense lightening storm I can easily disconnect all my plate-to-radio(s) coax patch cables for ultimate protection!

If you do not want to mount the plate IN the house wall then mount the plate ON the house perpendicular to the wall very near to the coax HAM shack entrance. Run the coaxes on one side of the plate, clear of the house entrance, then from the opposite side of the plate run the cables and internal station ground conductor into the house. Make the ground plate your single point ground to your internal shack ground! The closer the connection between the nearest ground pipe and the ground plate the better the conductivity.

The ground plate is the mounting bulkhead for surge/lightning protectors. The best protector is the PolyPhaser™ type! The PolyPhaser blocks surge energy by redirecting the energy into the ground system. This also means that you need enough of a ground system to dissipate the initial surge energy and the system ringing energy.



Ground Pipe/Rod placement

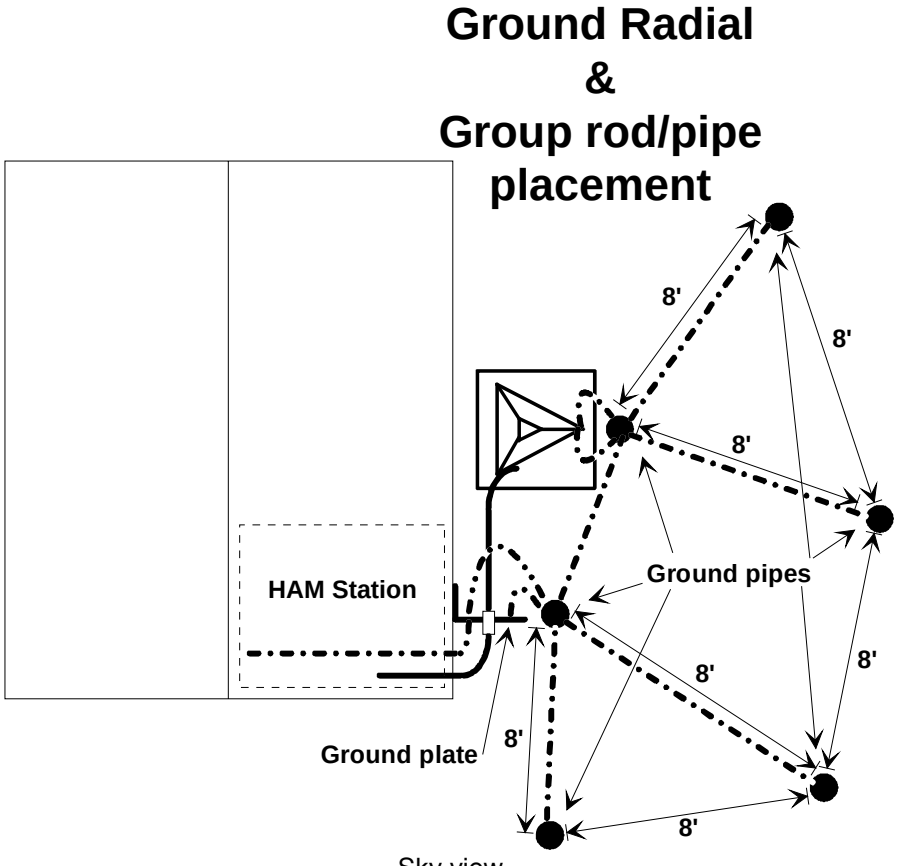
One of the biggest issues facing you is HOW MANY ground pipes/rods should you install? This is hard to determine as it is based on soil conduction, how potent are average lightning strikes, how much property do you have, and what can you afford? If you look at a commercial system they have multiple ground radials (seven or more) each 32 feet long and four ground rods on each radial. Some of the ground rods can be sunk as deep as 40 feet. This is NOT in my budget!

Obviously, the more ground radials and ground pipes/rods the better. I try to run at least three ground pipes in a non-tower HAM shack. One nearest to the coax cable entrance point (the shack ground), and at least two more ground radials with ground pipes at their ends separated by at least eight feet from the shack ground rod and separated by at least eight feet.

The tower increases the potential of a lightning strike so in addition to the above scenario with two or more pipes should be placed just for the tower. Place one pipe near the tower base and the other pipe eight feet away. The best grounding is one that makes contact with the water table (that's about 80's below my home). Falling short of that it is to dissipate as much energy as possible into the earth ground. By driving the grounds directly down attempting to traverse as many soil layers as possible energy can be dissipated into these various soil layers. Some soils conduct better than others - dry sand being the worst followed by hard clay. (But hard clay layer may have some amount of water riding on top the clay seeking penetration points.)

Another idea I've been kicking around is tapping into my septic 900 ft leach field system or the sump pump drain field tile system that is 1000's of feet. All these system pipes are plastic but the added moisture should dissipate energy over a large area nicely – just may be a little smelly during installation!

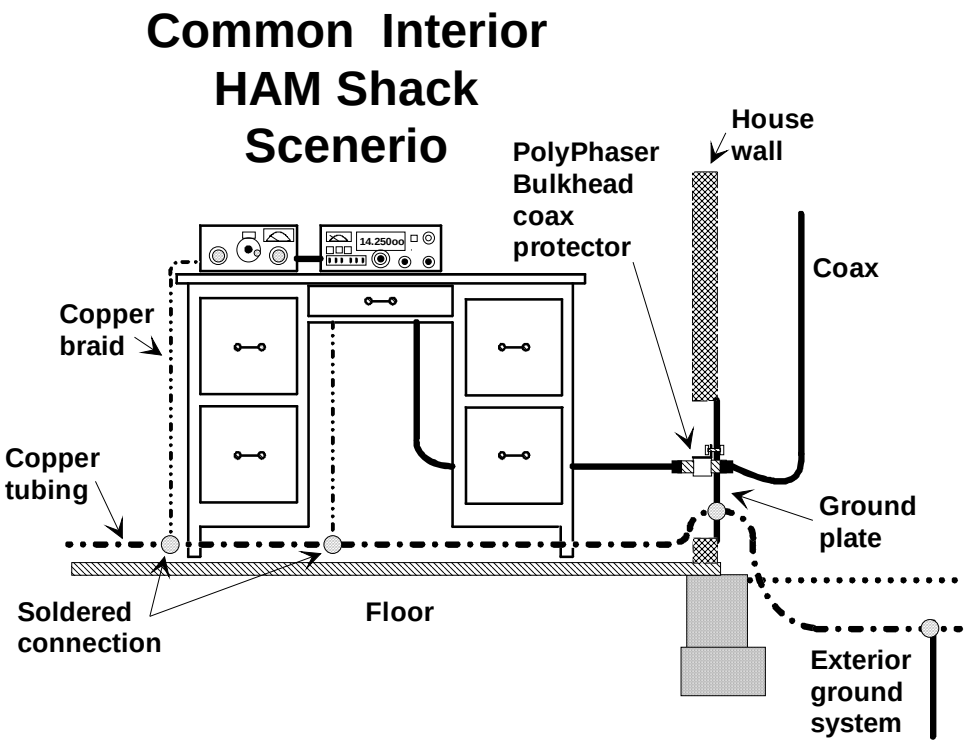
Placing the ground pipe/rod at a 45° angle can increase the overall length of the radial and allow some energy to be dissipated. Angled ground pipes/rods are often used in rocky soil.



Interior Ground connections

The interior ground conductor is just as important as the exterior ground system. I run ≥1/2" soft copper tubing from the ground plate along the mop-board behind the HAM station desk. Using old RG-8 coax cable I strip off the outside plastic coating to expose the braid. I strip off the braid using it as equipment leads to the soft copper pipe. Keep the braid ground strap as short as possible I solder the braid to the mop-board copper tubing. On the equipment end either heavily tin the braid and place a hole in the tinned area or solder an eye/folk lug to the braid. Connect the braid to the radios, antenna tuner, power supply, etc. Most radio equipment comes with an extruding ground bolt & nut - if not find a good chassis screw to attaché the eye/fork with washer.

My goal is to have an effective ground connection with short ground straps keeping the connections clean, affective, and unobtrusive in appearances.



Extra Writers NOTES:

a. Watch out using push-up masts. They may NOT have good inter-section conductivity. Additional ground strapping between sections may be required.

b. Use conductive grease to prohibit moisture from all exterior ground connections. Eliminate poor conductivity before it happens.

c. Use stainless steal clamps, bolts, washers, and nuts on all exterior ground connections, especially where making contact with copper.

d. The frequency of typical lightning is between DC to 1 MHz.

e. I did not cover grounding guy wires due to the fact that most installations use one or more insulators on each guy wire to keep the wires from becoming parasitic conductors reducing RFI concerns. Or many HAM's use the guy wires (with judicious insulator placement) as make-shift inverted "V" antennas or top-hats. So grounding of the guy wires defeats these ancillary uses.

f. Any conductor that could carry lightning should not make any bends smaller than a nine inch radius - the larger the radius the better. This requirement holds special significance to the connections between the tower, mast, and ground plate!

g. NEVER use your radio coax shield as your ground to the antenna tower.

h. Additional reference material sources:

Military HDBK-419 title

GROUNDING-BONDING and SHIELDING FOR ELECTRONIC EQUIPMENT'S and FACILITIES

Military STD-461A title

REQUIREMENTS for the CONTROL of ELECTROMAGNETIC INTERFERENCE and SUSCEPTIBILITY

PolyPhaser™ GLEP title

The "GROUNDS" for LIGHTNING and EMP PROTECTION

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