

By Ron Block, KB2UYT

Lightning Protection for the Amateur Radio Station

Part 3—In this final installment, the author shows how to develop a good external ground system to complete your station's protection.

Establishing a Good Ground

Now that the SPGP (Single-Point Ground Panel) is connected through the wall to the outside world, there is still a lot of work to do. It's necessary to switch from brainpower and the challenge of getting copper strap through walls to the brute force required to establish a good ground system. The operative word here is *system*—not a ground rod, but a network of interconnected ground rods.

The primary purpose of the external ground system is to disperse as much of the lightning energy as possible into the earth before it follows the feed line into the radio station. No matter how hard one tries, some of it will follow the coax, which is why you created the protection plan for the radio equipment. The easier you make it for the strike energy to dissipate in the earth before it gets to the radio station, the less your equipment protection plan will be stressed.

With great diligence, hard work, no real estate restrictions, plenty of funds and highly conductive soil, it is possible for up to 90% of the strike energy to be dissipated in the earth, leaving just 10% heading for your equipment. This would be quite an accomplishment. In many commercial sites it doesn't work out that well and rarely, if ever, for the Amateur Radio station—there are always restrictions. Let's see what should be done and then adjust to the home environment's restrictions.

Figure 13 shows what has to be done. In the center, the

concentric triangles represent the tower. Ideally, the tower is separated from the house by 20 to 50 feet. This distance provides sufficient room for the dissipation of the magnetic fields during the strike event. This distance also takes advantage of the natural inductance of the antenna feed lines to limit the amount of surge and allow more time for the tower grounding system to absorb the strike energy.

Radials and Ground Rods

Spreading out from the base of the tower is a set of eight radials. While the number of radials required for a particular installation will be dependent on the soil conditions in your location, the system shown here is a reasonable start. Each radial is a bare copper wire (preferably, strap) buried 6 to 18 inches below grade. The radials should be positioned so that the energy is dissipated away from the house.

Connected to the radials are ground rods. The ground rods are spaced approximately twice the length of a ground rod. For an 8-foot rod, the spacing would be 16 feet. During the strike, each ground rod has a cylindrically shaped region of influence centered on the ground rod. This is the region in which the ground rod disperses the strike energy. If the rods are placed closer, the regions of influence begin to overlap and the ground rod's ability to disperse energy is diminished. Although this overlapping does not harm the ground system,

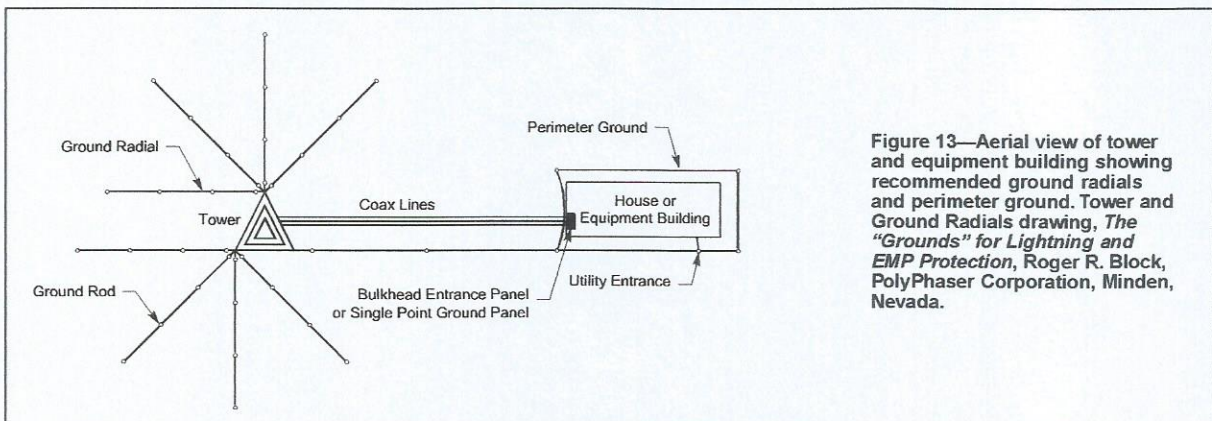


Figure 13—Aerial view of tower and equipment building showing recommended ground radials and perimeter ground. Tower and Ground Radials drawing, *The "Grounds" for Lightning and EMP Protection*, Roger R. Block, PolyPhaser Corporation, Minden, Nevada.

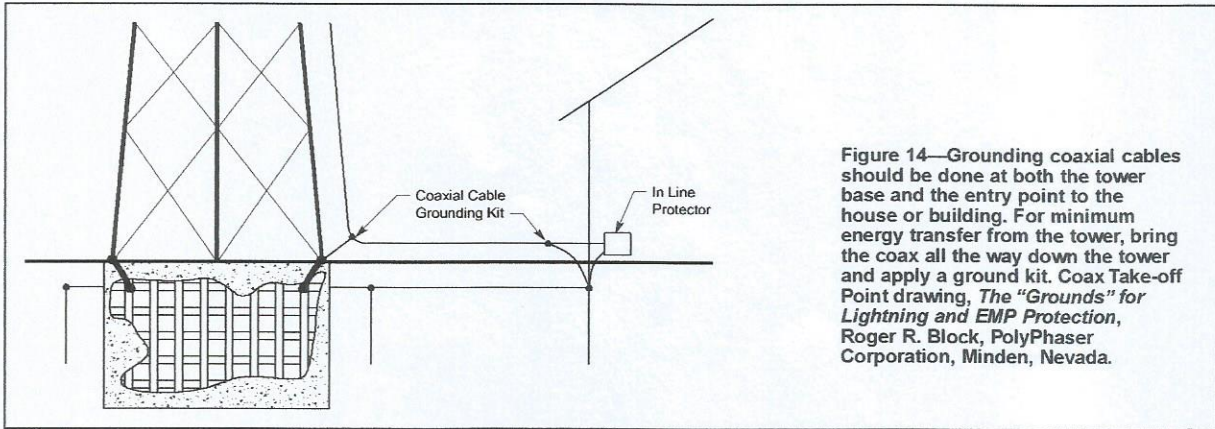


Figure 14—Grounding coaxial cables should be done at both the tower base and the entry point to the house or building. For minimum energy transfer from the tower, bring the coax all the way down the tower and apply a ground kit. Coax Take-off Point drawing, *The "Grounds" for Lightning and EMP Protection*, Roger R. Block, PolyPhaser Corporation, Minden, Nevada.

it does increase the cost since more rods are used.

Ideally, the connection between a radial and its ground rod should be made using an exothermic bonding process. This connection will most likely outlast the life expectancy of the ground system and you won't have to do annual inspections. A number of manufacturers supply the molds and fusing material for a variety of cable/strap and ground rod sizes. Two of them are Erico Incorporated (www.erico.com) and Alltec Corporation (www.allteccorp.com). If the exothermic process is not used, mechanical clamps that can be used to connect the radial to the ground rod are available. All mechanical connections must be inspected annually or more frequently to ensure the integrity of the system.

Ground rods must be mechanically driven into the ground. This is the only way to ensure that the rod achieves a reasonable "connection" to the earth. Drilling a hole and then back-filling the space around the rod is not acceptable.

While a very long radial/ground rod system is good, electrical and economic considerations come into play. Analyzing the average cost of installing an additional foot of the grounding system versus the benefit of a lower impedance system, the break-even point is somewhere around 80 feet. For practical purposes in areas with reasonably conductive soil, the maximum length of a radial should be limited to approximately 80 feet. If the impedance of the ground system needs to be lower, additional radials should be used as opposed to longer radials.

Some caution must be exercised when laying out the radials. If a radial comes within 4 feet of a metal object, it must be bonded to the metal object. The 4-foot rule applies to objects that are above, below, to the left or to the right of the radial. This includes metal fence posts, kids' swing sets, buried fuel tanks, and so on. Be sure to watch out for dissimilar metal properties when bonding to these objects.

Care must be exercised when connecting the radials to the tower. Most towers are zinc-coated steel (galvanized). Connecting a copper wire or strap directly to the tower leg will cause the zinc to erode, allowing the base steel to oxidize (rust). This in turn will increase the resistance of the connection and over time may threaten the mechanical strength of the tower segment. One solution to this problem is to use a buffer layer of stainless steel between the zinc and the copper. Several manufacturers offer tower leg clamps.

If you are constructing a new tower you can use the tower base as a "ground rod." Called a Ufer ground, it utilizes the rebar that reinforces the concrete base as an excellent ground connection. The rebar itself must be electrically interconnected so there are no spark gaps and there must be at least 4 inches of concrete between the rebar and the surrounding earth. If

this is done, a wire can be brought out from the rebar and attached to the tower leg. A great big ground rod! No, you will not blow up your concrete—the other radials with ground rods will handle most of the strike energy. Since you must put rebar in the concrete anyway, use it to augment your ground system.

There are two more items that need to be highlighted in Figure 13. The first is that the SPGP (or bulkhead entrance panel) is connected to the tower ground radial system. This connection should use the same material and ground rods as is used for the radials via a buried path. If the distance between the tower and the SPGP ground point is more than approximately 100 feet, however, it may not be cost effective to interconnect the tower ground system with the SPGP ground system. In this case some portion of the tower ground system must be duplicated for the SPGP ground system.

The second item is the perimeter ground, shown in Figure 13 as going completely around the house or equipment building. This perimeter ground serves two purposes: first, it helps conduct the surge energy around the house, minimizing the ground potential differences under the house during the strike event; and second, it enhances the basic ground system by providing more connection points to the earth. The existing utility ground is also connected to the perimeter ground—this is a must!

Some Specifics

That's how it should be done; here are some general guidelines for adapting this to your specific situation.

- In general, doubling the number of radials lowers the impedance of the ground system by one half.
- Radials don't have to go in a straight line; they can follow the contour of your property or flow around obstacles. Make turns gradually (12-inch radius or larger).
- A perimeter ground that only goes three-quarters or half-way around the house is better than no perimeter ground at all. Although flowerbeds, walkways and driveways frequently present insurmountable obstacles, do your best to get most of the way around. The perimeter ground must at least connect to the utility ground.
- Short ground rods are better than none at all. Just place them closer together spaced at twice their length.
- Soil doping can improve soil conductivity. Be aware that some additives may cause ground and water pollution and can shorten the life of the grounding materials.
- Where possible when installing a new tower, place it at least 25 feet from the house; 30 feet is even better. By placing the tower at some distance from the house, you minimize the amount of magnetic energy that will couple from

it into the wiring of the house. In addition, you take advantage of the inductance of the coax line in limiting the surge energy headed toward your equipment. Don't get too carried away with the distance; the added feed line also attenuates your signals.

• If you are fortunate enough to have multiple towers, each should have its own ground system of radials and ground rods. If the towers are within 100 feet of each other, a radial should be used to interconnect the towers.

Coaxial Cable Grounding

Each coaxial cable traversing your tower needs to be properly grounded to the tower. The first point is at the top of the tower where the coax connects to the antenna. The second point is where the coax leaves the tower to go to the radio equipment. This take-off point should be as close to the base of the tower as physically possible. The third point, for towers taller than 150 feet, is every 75 feet down the tower as measured from the top.

Depending on the height of the tower (inductance) and the severity of the lightning strike (current), the tower could easily have an instantaneous voltage difference between the top and the ground that exceeds 100 kV. In simplified terms, if the tower is viewed as if it were a very long resistor with one end connected to ground and the coax take-off point as a tap point on that resistor, you can begin to appreciate the problem associated with allowing the coax to leave the tower at any point above the bottom. For a 100-foot tower with a coax take-off point at the 10-foot level, approximately 10% of the tower energy (10 kV in this example) will follow the coax to your equipment. If you lower the connection to the 1 or 2-foot level, the energy flow will be correspondingly lower.

The grounding of the coax to the tower should be accomplished using a commercial-type grounding kit followed by the application of a commercial grade waterproofing material. Be careful of dissimilar metals when connecting the grounding kit pigtail to the tower.

In addition, another grounding kit should be applied to the coax just before it enters the house. This will remove some additional energy from the shield of the coax and further minimize the stress placed on your protection system. See Figure 14.

Special Considerations

Numerous Amateur Radio stations will be in locations that make it impractical or impossible to follow some or all of the advice given so far in this article. For those stations there are some things that you can do to achieve a reasonable level of protection for your equipment.

First, establish an SPGP for your equipment by creating a box-level schematic of your radio station. Identify and procure the appropriate protectors for all of the I/O connections to the radio station. Mount them on a common conductive surface. Where your installation varies from the ideal may be that the SPGP cannot be connected to an external ground.

As a substitute for an external ground, locate an alternative conductive path. Here are some recommendations for potential sources. These are in the order of most to least desirable.

- Building steel
- Stand pipe
- Metal cold water pipe
- Metal building skin
- Electrical system safety ground

Even though many of these ground choices are highly inductive and will not function as a good RF ground, the goal is to survive a lightning strike event by ensuring no current flows on the radio equipment I/O connectors. This is achieved through SPGP grounding techniques, which maintain an equal potential between equipment chassis during the strike independently of how the SPGP is grounded. For small upper-floor

radio stations, this will work just fine.

Operating Safety

No matter how good your installed lightning protection plan is, you *cannot* be in electrical contact with the radio equipment during a lightning strike event. Although there is no current flowing between the radios in your radio room, all of the equipment will be statically elevated above ground. If you are holding onto the microphone or the key during the strike event, you are now the path of least impedance to ground from the protected and now elevated equipment chassis. This ground path can be to the rebar in the concrete floor below your feet or to a nearby electrical wire or water pipe.

Consider getting a storm warning device capable of sounding a warning when lightning activity is within 10 miles of your radio station. (Lightning detectors are available commercially, or you can build one; see Radmore, "A Lightning Detector for the Shack," Apr 2002 *QST*, pp 59-61.) When the alarm sounds, leave the radio room. If your protection plan is installed correctly, you may leave the equipment connected and powered-on—but you must leave the room. Commercial radio operators get away with operating during lightning strikes because most of their equipment is remotely operated—just like a repeater.

More Information

After you have implemented the guidelines presented here and if you have questions (recognizing that every site is unique) feel free to contact me. Be aware, the first thing that I will ask you to share with me is your box-level schematic and some physical characteristics of your radio room and antenna farm. With this information as a reference, we can discuss your situation. Please forward a copy of the appropriate information before contacting me. Some additional information is also available on the WR Block & Associates Web site at www.wrblock.com.

Thanks

Many thanks go to Roger R. Block, my brother and founder of PolyPhaser Corporation, for his input in the preparation of this article.

Ron Block, KB2UYT, has been a PolyPhaser distributor and consultant since 1989 and has completed The Lightning Protection Course by PolyPhaser. He is the chairman of the Amateur Radio Station Grounding forum at the Dayton Hamvention and has been a guest speaker at various Amateur Radio club meetings. The author's brother, Roger, founder of PolyPhaser, reviewed this article for technical accuracy.

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[The resources sidebar that appears in Part 2 of this series (July 2002 *QST*, p 52) was not meant to be a complete list of manufacturers and suppliers of lightning detection equipment. To access the ARRL *TISFind* database, see www.arrl.org/tis/tisfind.html, and search for the key words "lightning" and "ground."—Ed.]

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