Lightning Primer

by

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There are definitely numerous opinions on the subject of lightning as well as on the related, but completely separate, subject of r.f. grounding. I am not implying that the ideas expressed by me are the only way of doing things. However, they have proven their worth over a number of years of implementation in the field.

First of all let me set forth my credentials: I have been a licensed amateur radio operator for over 42 years and have held a commercial radiotelephone operator's license for over 39 years. My college degree is from the Georgia Institute of Technology, better known as "Georgia Tech". In addition, I hold certification from the Personal Communications Industry Association in the two-way radio field. Also, I have certification as a Registered Communications Distribution Designer that is administered by the Building Industry Consulting Service International. This is "akin" to, but definitely not the same as, a Professional Engineer but specializes in the communications industry and is recognized on an International scale, not just statewide as the PE. I have been officially employed in the telecommunications industry since 1965 when I was a junior in college.

For over ten years I was employed at Texas Utilities (now "TXU") with primary responsibilities for their two-way and microwave radio systems. In addition, for the last five years of employment I also handled inspections, etc., of the infrastructure data wiring, etc. In May of 1999, TXU basically eliminated the telecommunications department and since then I have been doing consulting, writing, and even repair of "boat anchor" amateur equipment for others. I have been presenting talks and seminars on lightning protection and r.f. grounding for a number of years to various organizations including amateur radio groups. My presentation was video recorded this past summer and is now available (or so I am told) to colleges and universities for use in their education processes.

Now, to get started on the subject of lightning:

First of all, each and everyone have been "hit" by lightning at some time in their life. In fact, many people are "struck" at least several times a month, if not daily! Impossible you say! No, just walking across a carpeted floor or sliding across the seat of an automobile produces "static electricity". When you reach for a "grounded" object, a small "spark" is drawn from you to that object. That is nothing more than a lightning strike!

A simplification of the mechanics of a lightning strike consists of a charged mass (usually, but not always a cloud bank) that moves into an area. Since nature likes to remain in balance, the presence of this charged mass causes an opposite polarity charge to start to be drawn from the Earth. When the potential of the differences between these two oppositely charged masses reaches certain intensity, the equalization of potential (the reduction to zero voltage) takes place. This equalization is better known as a lightning strike.

When anything is erected above the surface of the Earth, it starts "attracting" energy from an area that is approximately a circle with a radius of twice the height of the item. For example, if a vertical antenna is erected that has a height of 50 feet, it "attracts" energy from a circle with a radius of 100 feet (or diameter of 200 feet). Now, the cross-sectional area of a tube with a diameter of 0.75 inches and a wall-thickness of 0.32 inches (this is a very common size used in vertical antennas) equates to an area of 0.075 square inches. This is the total surface area from which the energy has to be dissipated. The area from which the vertical is "drawing" energy is 31,416 (to the nearest square foot) or 4,523,899 square inches. The ratio of the 0.075 square inch "radiating surface" to the area from which the energy is drawn is 60,318,647

If a charge equal to 1 volt per square inch is "acquired" from the surface of the Earth, this becomes over 60 million volts per square inch at the top of the antenna! That is one "heck of a" potential to be equalized.

There are two definite theories in the area of lightning protection. The first is to take whatever precautions are necessary to prevent a strike (and there are definitely some). The second is to ground the "hell" out of everything to allow a strike to be taken without doing any damage. My ideas are to take the precautions against taking a strike and then grounding everything "just in case"! Frankly, there is nothing that will insure absolutely that you will never take a lightning strike. However, there are relatively simple things that you can do to cut this possibility by 99.99 percent.

Contrary to popular belief, lightning does not start from the sky, but starts from the "ground up". The vast majority of the equalizing charge does come from the charged mass in the sky. However, the strike actually starts from the ground in the form of a "feeler". If you can keep these "feelers" from starting, you will keep lightning from striking. How to do this will be covered in the next installment.

If "feelers" do not start, there will not be any chance of a lightning strike. Therefore, if at all possible, dissipation devices should be installed on the antenna structure. Unfortunately, if the antenna is a single vertical, it is extremely difficult to install a dissipation device unless it is also used as a "top hat" loading device and the antenna itself must be grounded (shunt feed, etc.).

When a tower, mast, pole, etc., is used, then such devices can be installed with no effect on the antenna(s).

The purpose of a dissipation device is to dissipate the charge "acquired" by the antenna system before it reaches the potential where a "feeler" is formed. This is accomplished by having a relatively large surface area at, or near, the top of the structure to "handle" the charge ("spline ball"). Or, in the case of a dissipation brush, a large number of "points" available for this purpose. As the charge is acquired, the dissipation device "bleeds" off the electricity into the atmosphere. In some cases, during periods of extreme activity, the dissipation device may actually "glow" (corona forms). This is fine! When a corona is present, there is no chance of a "feeler" starting.

Dissipation devices need to be installed on each leg of a tower, not just one leg. They need to go at the top, or within a foot or two of the top of the tower. However, they do not have to go on the mast, etc., that comes out of the top of the tower. If the tower is less than 100 feet in height, normally one set of dissipation devices will suffice. At about 100 feet, two sets should be used, one set "half way up" and the other at the top. With heights over 150 feet, dissipation devices should be installed every 75 feet starting from the ground level.

"Spline balls" are available from a number of commercial sources and cost from over $100 upwards. These are normally constructed of stainless steel and consist of a large number of metal strips connected to a central point. Dissipation brushes are also available commercially and can be easily constructed by the amateur radio operator for about $5 to $10 each. In addition, some persons have been able to find steel brushes made for chimney sweep activities for about $15 each. However, I have never been able to find these!

The construction of dissipation brushes is easy. If the brushes are to be mounted at the top of the tower (sticking "straight up"), then a 12 inch long piece of ¾ in diameter galvanized electrical conduit (e.m.t.) is used. Two "notches" 1 inch long are cut at right angles in one end. Using galvanized electric fence wire (available in ¼ mile reels at home improvement centers for under $10) the brush is constructed. Cut about 150 lengths of wire, 15 inches long, from the fence wire. Put a hose clamp that fits the ¾ inch conduit around the notched end. Then, with all the wires held together, insert the fence wires into the conduit. Next, tighten the hose clamp. Then, using acid core solder and a propane torch, solder the conduit and the wires together.

To attach the dissipation brush to the tower, use two metal hose clamps and tighten well. Since the purpose of these devices is to "drain" the charge, the physical connection of the hose clamps between the tower (or mast) and the dissipation brush is sufficient. If it is installed on a wooden pole, then a ground wire (12 gauge is normally sufficient) will have to be run.

For brushes to be used on the sides of the tower (or they can be used on top as well), take an 18 inch long piece of conduit and bend it about 45 degrees 6 inches from one end. Then cut the notches at the other end. Follow the instructions above for building the dissipation device. Remember to make one device for each leg of the tower.

Installing these devices will help considerably in preventing a lightning strike. However, there is nothing that will insure that you will NEVER take a strike. But, by installing dissipation devices you will cut your probability of taking a strike by about 99.99 percent.

The next installment will cover proper grounding techniques for tower legs, etc., and for the grounding of coax before it enters the shack.

Direct grounding of the tower, mast, etc., is of prime importance for lightning protection. Even if dissipation devices are installed, they are not 100 percent effective in eliminating the prospect of a lightning strike. Therefore, additional precautions must be taken "just incase" you take a strike.

First of all, NEVER use a ground intended for r.f. for lightning protection (conversely, never use a lightning ground for r.f.). The methods use for getting a good r.f. ground are different from those used to get a good ground for lightning protection.

Each tower leg MUST be grounded separate from the other legs. This can be accomplished by driving solid copper-clad steel rods into the ground at least six inches outside of the concrete pad on which the tower is mounted (or is actually "in") directly in-line with the tower leg. Next, use #6, or heavier, copper wire for the ground wires. It doesn’t really matter if the wire is insulated or not. For this purpose, stranded is better than solid. It is not the current carrying capability of the wire, but the fact that solid wire is more easily distorted which definitely affects the lightning protection ability.

It will depend on how far out the ground rods are from the tower legs as to how high they should be attached to the tower. The further out the rods, the higher you have to go on the tower. The "angle" between the ground wire and the tower should not be greater than 30 degrees, and the smaller the angle, the better it is.

Remove about two inches of insulation from each end of the wire if it is insulated. Next, attach the wire directly to the tower leg using a good, heavy, type of clamp (these are available at home improvement centers). Do NOT use the "hole" in the clamp that is provided for wires, but clamp the wire directly to the tower leg (the end of the wire that is clamped will be up). Some people like to "CAD weld" these ground wires, but I do not like to do this. Bring the wire downward in a very gentle "arc" to the ground rod. Using a similar clamp as on the tower leg, clamp the ground wire directly to the ground rod.

What ever you do, do not have any arc in the ground wire with less than a 12-inch radius. Never reverse direction of the ground wire even the slightest (lightning will not usually follow the wire if the radius is less than about 10 inches and will "jump" to "who-knows-where").   Any "right" angle in your ground system will cause the lightning charge to go elsewhere. This is one of the reasons that I do not like using CAD welds for the attachment of the ground wire to the tower (it puts a "right" angle in the system). Also, especially on the smaller diameter tubing towers that are the most commonly used on amateur systems, CAD welding can greatly weaken the strength of the tower leg if not properly done.

Coax should be grounded at the top and bottom of the tower. This includes Heliax, and any other type of shielded cable. This can either be accomplished by purchasing grounding kits from Andrew, or other cable manufacturer, at a significant cost, or by making your own for less than 50 cents per connection. I choose to make my own!

Remove about 1 inch of the outer sheath of the coax (baring the shield). Next, take a length of braid (like has been removed from an old piece of RG8/U, etc.) about 6 inches to 12 inches long. Using a small hose clamp, clamp this braid to the shield of the coax. Then, use the very cheap black plastic tape (the 39 cents a roll stuff - do not use any 3-M product) to tape the connection very well to waterproof it. In a week, or so, of exposure to the sun, this "cheap" tape "congeals" into a sticky, "gooey", waterproof mass. The "good" 3-M tape comes loose when exposed to the elements. Decibel Products used to include a roll of this "cheap" tape with every one of their commercial antennas to waterproof the connections. I have taken apart connections that were over 20 years old waterproofed with this type of tape. They looked just like they had been made (no corrosion, etc.!).

When each of the coax cables has had a ground wire attached, then attach these to one of the tower legs using two hose clamps to hold them in place. Do the same thing at the bottom of the tower. If there is over 10 to 15 feet between the tower and the entry into the building, then another ground should be put on the shields of the coax cables. This ground should be attached to some type of ground plate, or, they can all be connected together and brought through a single ground wire to another ground rod driven at the side of the building.

If properly done, there is no reason to disconnect your antennas whenever a thunderstorm comes into the area. Frankly, my antennas have been up over 29 years and they are never disconnected. I have had no damage at all. My primary tower has a 3-element 20 meter monobander, a DB-1015 for 15 and 10, a 2-element homebrew yagi for 12 meters, a 3-element six meter, and stacked 11-element beams (2 each) vertically polarized for 2 meters. My secondary tower has a 7-element 2 meter yagi, 11-element 222 MHz yagi, and 3-element 6 meter yagi installed. None of these has ever taken a strike.

Remember that good grounds are not "pretty". You NEVER want a large angle bend. You NEVER reverse the direction of the ground.

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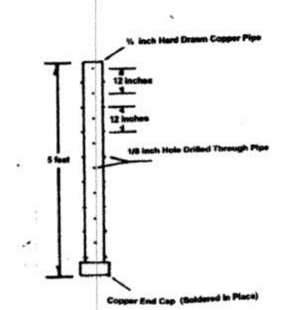
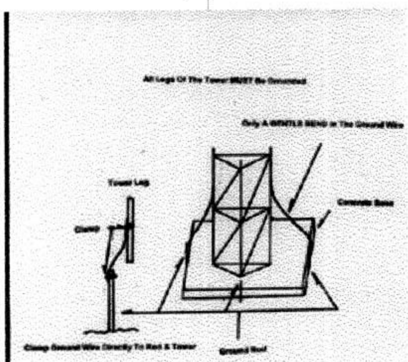
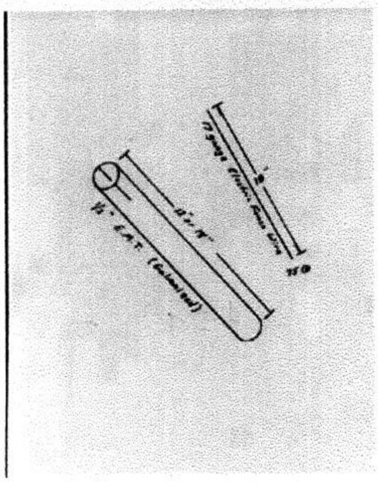


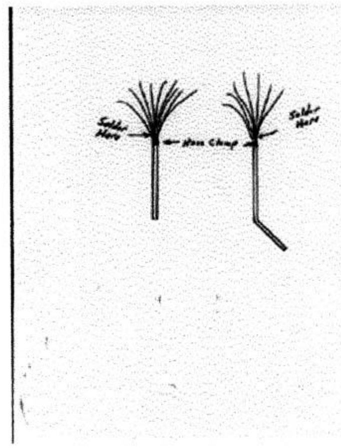
Details of Chemical Ground Rod
Fill With Rock Salt After Driving In Ground
(Drawing Not To Scale)

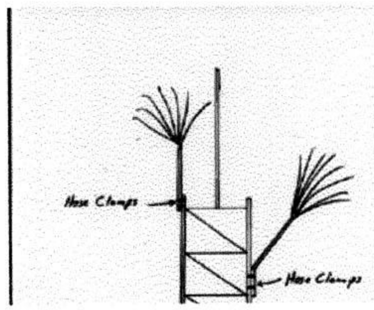
Figure 6: Graphic representation of the ground rod

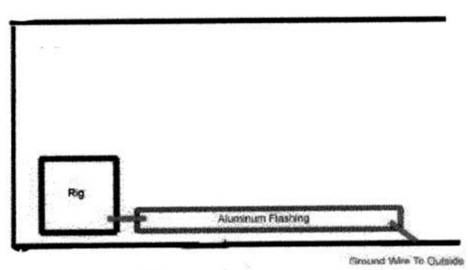


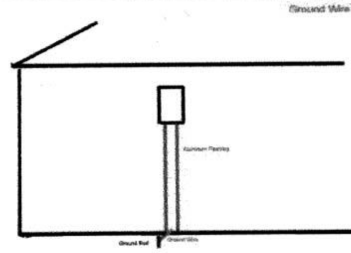
Grounding Of The Tower (Or Mast)
Use At Least #6 Stranded Wire
Or Heavier (i.e. 000)
The Smaller The Number
The Larger The Wire











2nd Story Grounding

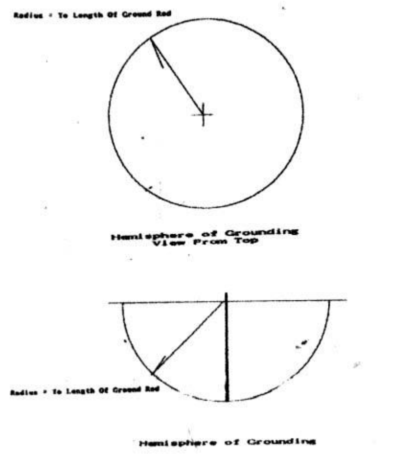


Figure 1: Graphic representation of the "hemisphere of grounding"

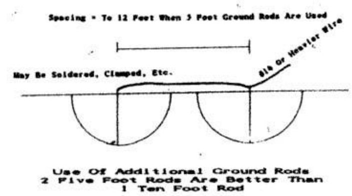


Figure 2: Graphic representation of grounding effectiveness of two ground rods

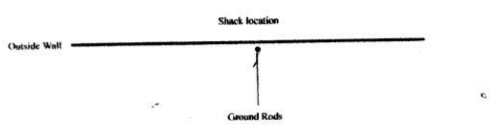


Figure 3: One ground rod should be as close to the shack as possible

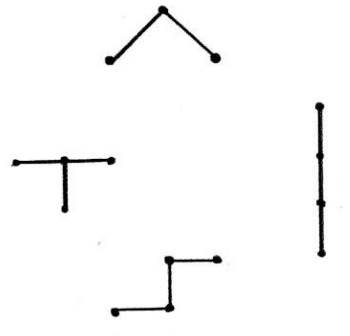


Figure 4: Ground rods can be placed in any geometric configuration as long as they are 12 feet apart for 5 foot long rods.

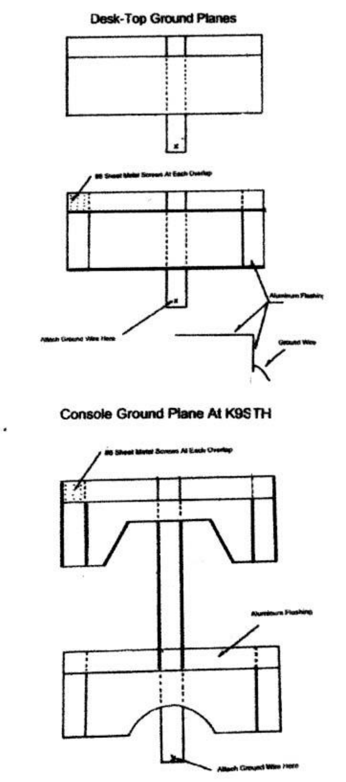


Figure 5: Graphic representations of placement of Aluminum flashing material.