Grounding for lightning protection

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In a previous job, I spent more that five years in lightning mitigation where I visited sites throughout the country to make recommendations to improve the survivability of equipment from lightning strikes. When my suggestions were taken, equipment damage fell to almost zero.
There is no protection from a direct strike.

Grounding for lightning protection is different from safety grounds as normally seen.
As long as all of the grounds are well connected a safety ground will do its job.
With the proper breakers, if there is a fault that can cause you harm, the breaker will open removing the source of power.

The intended purpose of the lightning protection system is to provide preferred paths for lightning discharges to enter or leave the earth without causing facility damage or injury to personnel or equipment.

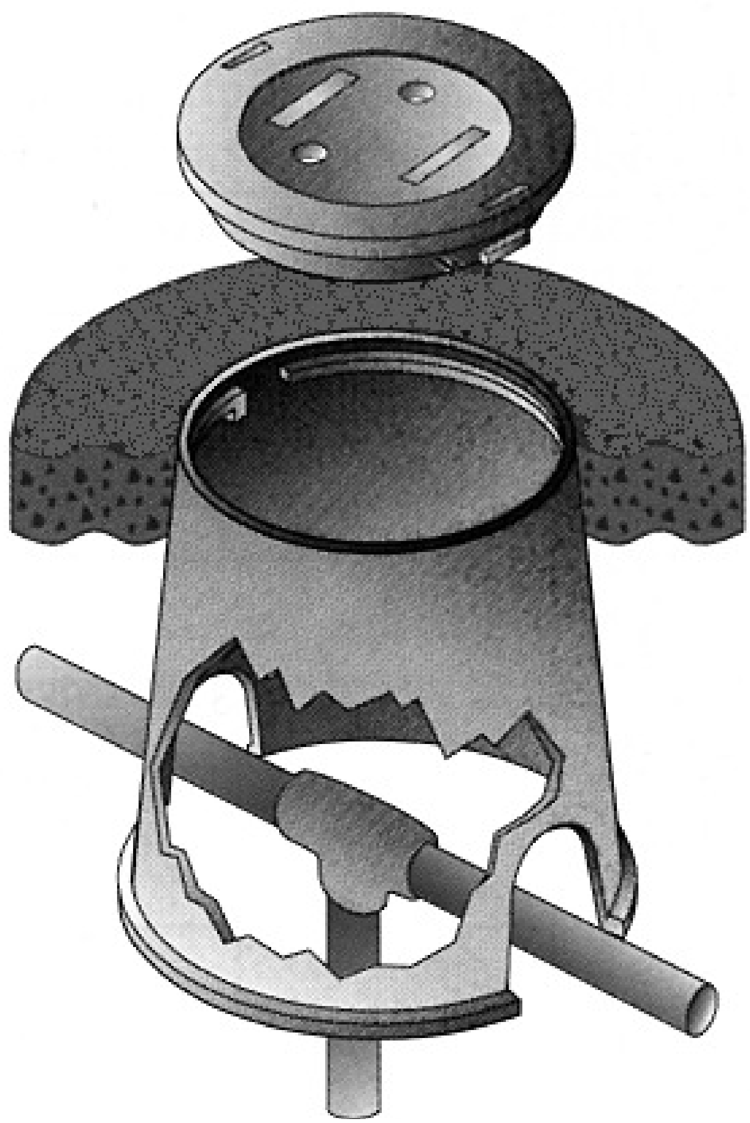
Lightning is a very high energy high frequency event and requires grounds that provide a very low impedance to ground without opening.
These grounds have to handle fault currents into the tens of thousands of Amperes.
All site lightning grounds have to be unified, that is connected together.
To provide site protection, all grounds have to be referenced to the same low impedance point. The lower the impedance the better the protection.

How do we do this?
It is not cheap, but probably cheaper than equipment replacement.
As they say, you can pay me now or pay me later.

To start with, we have to establish the unified ground.
Starting at the utility ground (you do have a utility ground with all wired services entering the building grounded at this point, don't you?)
From the utility ground to the tower, place ground rods along the straight path at a separation of at least twice the ground rod length.
That is, if you are using 8 foot rods, place them no closer than 16 feet apart.
All primary ground rods are to be copper or copper clad.
Drive these rods to at least 18 inched below grade or to the point of refusal.
This depth is somewhat important as this is generally below the frost line and the moisture content at this depth is somewhat constant.
Dig a trench connecting the rods to the depth of at least 18 inches.

Place a number 2 AWG or larger wire in the trench to connect the unified ground to the tower ground.
The connections to the unified ground, the ground rods and the tower are to be cad welded or attached similarly.

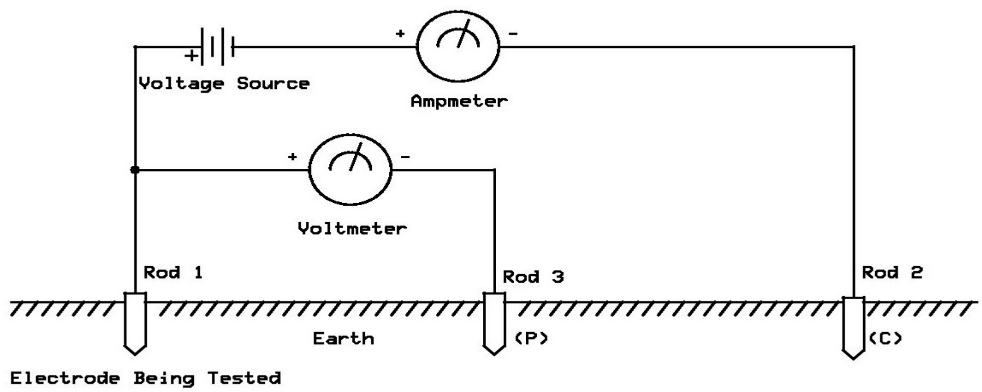
Compression fittings are not to be used. These can come loose and increase the connection resistance. The connections below grade should have an inspection port (ground test well) placed over the connection.



There are electrical covers made specifically for this, but, a Rain Bird© cover works very well and is used on a lot of commercial sites.

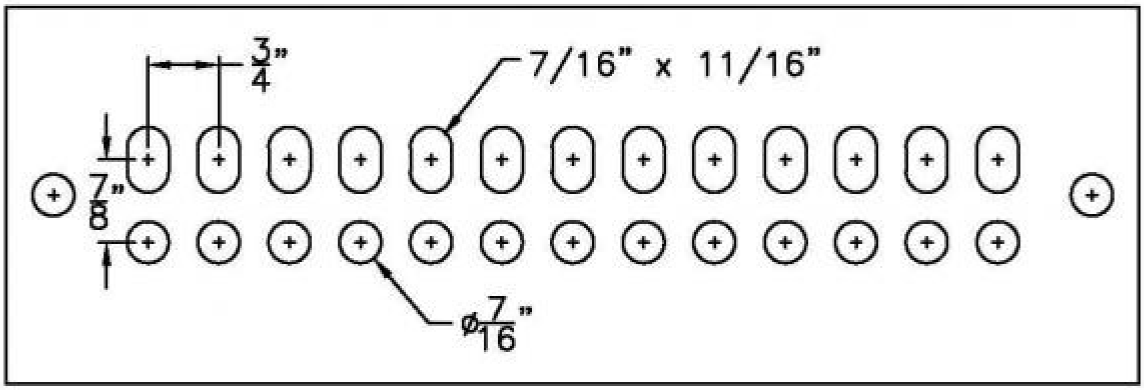
Around the base of the tower, place a ground ring about 8 feet in radius.
This ground ring is to be installed in the same manner as the ground from the unified ground to the tower.
This will require three rods placed equally around the circumference of the ground ring.
Again all connections are to be at least 18 inches below grade and cad welded.
This ground ring is to be attached to the tower at a minimum of two places.

At this point you have established a unified ground.
This ground should have a ground resistance as low as possible. Motorola requests a ground resistance of 5 Ohms or less. I have never seen a Motorola site with this low a ground resistance.
The more ground rods the better as long as they are no closer than twice their depth apart.



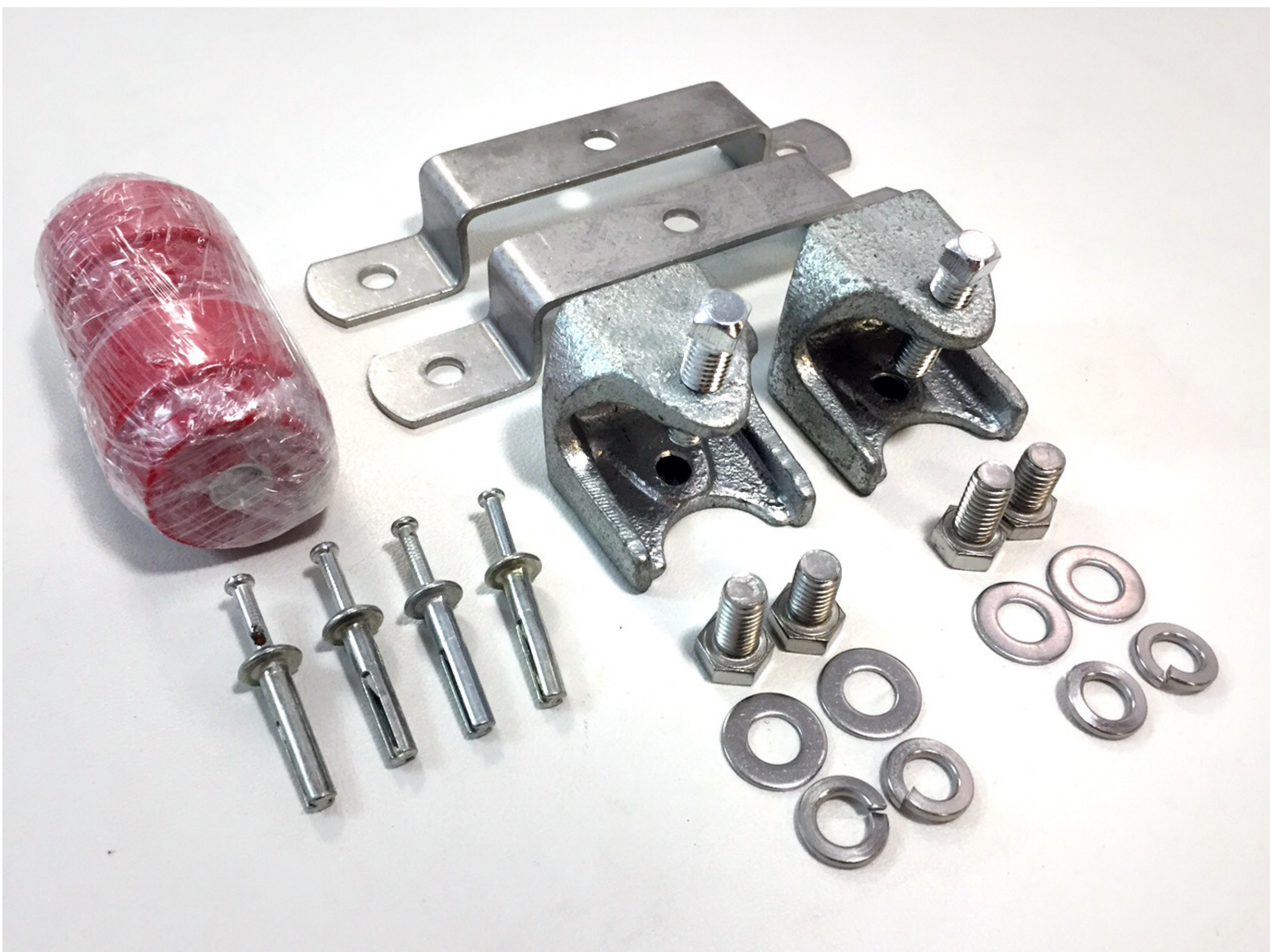
Ground resistance can be measured in a number of ways.
There is a clamp on ground resistance tester that is made by a number of companies.
It is quick and somewhat accurate if the instructions are followed. There is also the fall of potential ground resistance tester. This is the most accurate and is described in IEEE 81 Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Grounding System. This consists of the main unit and three ground probes. The first probe is the installed ground rod. The next probe is the potential probe and the third is the current probe. All three probes are placed in a straight line. The spacing between the probes is a function of the probe length and this distance is usually specified by the equipment manufacturer based on the voltage applied and the length of the probes. Ground resistance is computed using Ohms law. We know the applied current, we measure the potential impressed on the earth by the applied current and can therefore compute resistance.

Now we will address feed lines on the tower.
On the tower attach an external ground bus bar to the tower at the top and near the base where the feed lines will leave the tower coming to the shack.
The lower external ground bus bar should be mounted a low as possible.
This external ground bus bar is to consist of a copper plate made specifically for this purpose.
An example is a Harger GBU14210P which is 10"x2"x0.25".



This has the holes drilled to attach the feed line ground wires and will accommodate 10 ground wires. The drawing above shows 13 sets of holes.

There is a mounting kit also available which makes mounting easy for different towers and buildings.



The external ground bus bars on the tower ensure that the feed lines are as close to ground potential as possible.
The reason that the lower external ground bus bar is to be mounted as close to ground as possible is that they are part of a voltage divider.
The entire voltage from a lightening strike is impressed on the feed line from the tower top to ground.
We have to bring the feed line to the shack.
The voltage still impressed on the feed line is a function of the voltage divider from the top of the tower to the feed line take off point to ground.
The closer the lower external ground bus bar is to ground ensures that the voltage impressed on the feed line at this point is as low as possible.
The ground connection to the lower external ground bus bar should be cad welded or brazed and the grounding lead should be copper strapping or wire number 2 AWG or larger attached to the external ground bus bar in two places, preferably near the ends.

The feed line will go from the tower to the shack either buried or above ground.
At a commercial site, the feed line travels above ground, under an ice/cable bridge to protect the feed line from falling objects from the tower and to support the cables.
In this case the ice/cable bridge is also grounded. Very few hams will utilize an ice/cable bridge.

We will probably run the feed line on a stringer similar to the way that CATV coax is attached to the poles for distribution.
Few hams will choose the underground as this requires special coax to prevent water incursion when the cable is nicked from digging or other under ground damage.
Before the coax enters the shack, it is also attached to an external ground bus bar grounded the same as the one on the tower to ensure any remaining voltage on the feed line is shunted to ground.
Coax grounding kits are installed on each cable at the three external ground bus bars.
At the external ground bus bar at the shack, the coax goes through a surge suppressor that is bonded to the external ground bus bar.
This ensures that any coupled lightening strike energy on the center conductor is shunted to ground to minimize equipment damage.

An air terminal, placed at the top of the tower and properly grounded will provide a place for lightning to strike and be discharged to ground, bypassing your antennas and equipment. The air terminal is usually one to four feet long, depending on strike probability, and is made of copper, stainless steel or aluminum. In a commercial site the air terminal is bonded to the unified ground with a separate ground wire larger than number 2 AWG.

No lightning ground conductor will go through a metal pipe, unless bonded to the pipe at each end (the pipe acts as an inductor that impedes the high frequency pulse).
No lightning ground conductor will be encased in concrete, the concrete may explode due to conductor heating during a lightning strike.

With this, we have provided an adequate lightning ground external to the building.

To help prevent a strike static dissipaters have proven effective for the FAA and in places like Florida.
These are installed on the tower and other high points.
Their purpose is to bleed off the static charges before they reach strike potential.
The FAA uses these on their remote communications buildings.
These are mounted at the highest point on the building.

After the FAA started using these, lightning type damage dropped drastically.

All of the equipment inside the shack should be bonded to the unified ground.
One was to do this is to place a copper bar or strap about the same level as the operating table.
This bar or strap is to be connected to the unified ground by the shortest means feasible with a number 2 AWG or larger copper conductor. .
Each piece of equipment is to be grounded to this bar or strap with a piece of number 6 AWG or larger copper conductor.
The pieces of equipment should not be grounded together, but, each piece of equipment is to have a separate ground wire to the bar or strap.
If it is not feasible to braze or weld in the shack, use good quality brass nuts, bolts and star lock washers with properly crimped lugs on the ground wire.
The idea is to keep the impedance to ground as low as possible.
All ground wires inside and outside are to be as direct as possible and if a change in direction is required, the bend radius of any ground wire is to be greater that 8 inches.

Power line, control line and phone line suppression is a matter for a topic for another time.
These are addressed in the below listed references.

I have not used the ARRL book “Grounding and Bonding” as I have found many errors in it.
Most of this material is from Motorola's R-56 “Standards and Guidelines for Communications Sites”.
This manual references MIL-HDBK-419A parts A and B (Military Handbook Grounding, Bonding, and Shielding For Electronic Equipments and Facilities).
Further information is from FAA-STD-019e, Chg 1 (Lightning and Surge Suppression, Grounding, Bonding and Shielding Requirements for Facilities and Electronic Equipment).