Lightning Protection

The Challenge

The amateur is challenged to assemble the best radio station possible, enjoy the benefits of the hobby, and have the station operable during times of need. This can be a significant challenge especially considering the awesome capabilities of Mother Nature's lightning strikes. While she may have the upper hand as far as when and how much energy she delivers, you have the ability to influence how that energy is diverted into the earth. Said another way, you can implement a lightning protection plan that will protect your Amateur Radio station, even from a direct strike!

Lightning Characteristics

The conditions necessary for an old-fashioned summer afternoon thunderstorm are lots of moist air from ground level to a few thousand feet, cooler air above with little to no wind, and plenty of sun to heat the air mass near the ground. As the warm, moist air is heated, it rises quickly to heights where the temperature is below freezing, eventually forming a thundercloud. Within the thundercloud, the constant collisions among ice particles driven by the rising air causes a static charge to build up. Eventually the static charge becomes sufficiently large to cause the electrical breakdown of the air—a lightning strike. The average thunderstorm is approximately six miles wide and travels at approximately 25 mph. The anvil shape of the cloud is due to a combination of thermal layer (tropopause) and upper high velocity winds that cause the top of the cloud to mushroom and be pushed forward. The area of imminent danger is the area up to 10 miles in front of the leading edge of the cloud. When a lightning strike does occur, the return stroke rapidly deposits several large pulses of energy along the leader channel. That channel is heated by the energy to above 50,000ºF in only a microsecond and hence has no time to expand while it is being heated, creating extremely high pressure. The high pressure channel rapidly expands into the surrounding air and compresses it. This disturbance of the air propagates outward in all directions. For the first 10 yards or so it propagates as a shock wave (faster than the speed of sound) and after that as an ordinary sound wave—the thunder we hear. During a lightning strike your equipment is subjected to several huge impulses of energy. The majority of the energy is pulsed dc with a substantial amount of RF energy created by the fast rise time of the pulses. A typical lightning strike rise time is 1.8 ∝S. That translates into a radiated RF signal at 139 kHz. Rise times can vary from a very fast 0.25 ∝S to a very slow 12 ∝S, yielding an RF range from 1 MHz down to 20 kHz. However, the attachment point for a direct lightning strike has a time as fast as 10 nS. This RF content of the strike will have a major effect on the design of the protection plan. In addition to the strike pulses, the antennas and feed lines form tuned circuits that will ring when the pulses hit. This is much like striking a tuning fork in that ringing is created from the lightning's pulsed energy. Average peak current for the first strike is approximately 18 kA (98% of the strikes fall between 3 kA to 140 kA). For the second and subsequent impulses, the current will be about half the initial peak. Yes, there is usually more than one impulse. The reason that we perceive a lightning strike to flicker is that it is composed of an average 3 to 4 impulses per lightning strike. The typical interval between impulses is approximately 50 mS.

Vulnerability

Frequently, amateurs provide an inducement for Mother Nature to find us. For good long distance communications, we put our antennas on the top of towers and place the towers so that they protrude above the surrounding buildings or countryside. While this provides for great signal coverage, it also makes it easier for Mother Nature to find a shorter, conductive path to ground. The probability of having your tower struck by lightning is governed primarily by where you are located and the height of the tower. The other significant factor that affects the probability of being struck is the height of the tower above the average ground level. As you might suspect, the higher your tower, the higher the probability of being struck.

Identify What is to be Protected

The goal of the planning process is to establish a "zone of protection" within the radio room, as opposed to the whole house or building. Additional zones may be considered separately. The first step in the process is to identify what you want to protect. The immediate answer is, well, everything. While you can come close, you may run out of money, time, or energy. So let's create a priority list and work the list from high to low priority. Probably first on the list are the more expensive items associated with your radio station, usually the transmitting and receiving equipment. What follows on the list depends on just how you enjoy the hobby—the antenna tuner, linear amplifier, terminal node controller, or computer. Further down the list might be the antenna, rotor and transmission line. Each person's list and priority ordering will be different. The first step is to construct a complete block diagram of the equipment in your radio room starting with the top priority item. (You will make a separate plan for other areas needing protection.) This is usually simple and straightforward. In some installations it may be necessary to look behind the equipment to determine precisely the connections between each element. The accuracy of the diagram is important in determining the nature and effectiveness of the protection plan. If you have multiples of either, then they are probably listed in order of value. These are the heart of your radio station, so make them the starting point of protection plan which will in turn examine and diagram each element of the station.

Protecting Each I/O Line

The best I/O line protectors are connected in series between the surge and the circuit they are intended to protect. Series protectors, by design, have the capability to limit the amount of lightning strike energy your equipment will receive. The "better manufacturers" will specify the maximum amount of "let-through energy" your equipment will receive during a strike. It is normally specified as a quantity of energy in the milli- or microjoule range. When choosing a protector, select the one with the least let-through energy that meets all of the requirements for the connection.

Single Point Ground

The next step in the process will take us away from the By shorting all of the wires associated with an interface no current can flow through the equipment between the wires of the interface. Extending this premise further, by mounting all of the protectors in common, no current will flow between the I/O interfaces. Hence, no lightning surge current will flow *through* a protected piece of electronic equipment. To make this possible in the radio room it is necessary to establish what is known as a "Single Point Ground." This is the *one and only point* in the radio room where a ground connection is present. We need to be a little careful with the term "ground." During a strike a ground can be anything that is capable of being an energy sink. By this definition absolutely anything that is not at the same electrical potential can be a sink. Because electrical signals travel at about 1 nanosecond per foot, fast rise times may create significant potential differences for short times due to travel differences. The creation of a single point ground will be different for every installation. It can be as simple as a couple of protectors bolted together or a through-wall entrance panel, or as complex as a copper-covered wall upon which the protectors are mounted. Whatever form your single point ground takes it must be the only ground point for all of your equipment.

We all know that a conductor, no matter what size or shape, has inductance that increases with length. Connecting the SPGP to the external ground system should be done with the shortest possible wire. We all know that no matter what size, wire has inductance. Larger wire sizes have less inductance than the smaller sizes. We also know that RF energy travels near the surface of a wire as opposed to within the central core of the wire (skin effect). If we put these together and extend the hypothesis a little, it would seem reasonable to use a railroad rail-sized bus bar as an excellent connector between the SPGP and the earth ground. While the large bus bar would work well, it has lots of surface area and a massive core, the cost would be prohibitively expensive and it would be extremely cumbersome to work. We can have the benefits of the large bus at a very reasonable cost if we use multi-inch-wide copper strap instead, however. One and a half inch wide, #26 AWG (0.0159 inch) copper strap has less inductance than #4/0 AWG wire, not to mention that it is less expensive and much easier to work. We can use thin copper strap to conduct lightning surge energy safely because the energy pulse is of very short duration and the crosssectional area of this strap is larger than #6 AWG wire. The strap has a large surface area that makes it ideal for conducting the strike's RF energy. The goal is to make the ground path leading away from the SPGP more desirable than any other path. In order to achieve this we need to find the total amount of coax surface area coming to the SPGP from the antennas. The circumference of a single 9913 coaxial cable represents about 1.27 inches of incoming conductor surface. To make our ground path appealing to the surge energy, we ideally need more than 1.27 inches of conductor surface leaving the SPGP. Where the use of a single 1½ inch wide conductor leaving the panel is reasonable, a strap three or more inches wide would be better. Inductance is calculated on the length of the connection between the SPGP and the ground, as well as the number and sharpness of the turns. If you had three 7/8-inch Hardlines, a minimum strap width of 9 inches would be needed and 12 would be better. You now have determined what protective devices are needed and how to mount them for an effective barrier to lightning energy. Next month, the final part of the article will present guidelines for developing a good external ground to absorb and dissipate the lightning's energy.

Solder or weld the ground wire to the ground rod. The ground rod should be at least 8 feet long and solid such as copper.