LIGHTNING PROTECTION CHECKLIST

KEY ELEMENTS NECESSARY FOR THE PROTECTION OF EQUIPMENT & PERSONNEL FROM LIGHTNING

1. Use current division to control the dissipation of lightning strike energy on an antenna tower grounding system through multiple paths.

2. Separate the antenna tower from the equipment building by a minimum of 30 feet.

3. Use only a single point grounding system for the equipment building.

4. Use a bulkhead panel/waveguide hatch for all coaxial cable entry into the equipment building.

5. Coordinate the location of the (1) bulkhead panel bond, (2) power and telecommunications entry bond, (3) bond between antenna & equipment building, at the single point ground connection.

6. Isolate all wire-line communication services from remote ground with optical devices or isolation transformers.

7. Use AC power surge protection at main power entry and critical secondary panels.

To determine the potential for equipment damage or personnel injury from a lightning strike, perform the following risk evaluation. Check the number of items that describe conditions at your location:

☐ Lightning damage has occurred here before.

☐ Personnel are located here and use the equipment at this location.

☐ This location is associated with an antenna tower that is within 50 feet.

☐ This location is in an area of the country that has 30 or more thunderstorm days per year.

☐ This location requires AC power, and does not have surge protected power panels.

☐ This location requires wire-line telecommunication services which have not been isolated using optical isolation or isolation transformers.

☐ All equipment in this location is not bonded together at one single point on the building grounding system.

☐ This location has coaxial cables that come directly in the building without going through a bulkhead panel/waveguide hatch.
☐ The associated antenna tower at this location does not have a grounding system made up of at least 200 feet of buried bare ground conducting wire with multiple paths (minimum of 5, each 40 feet in length) away from tower base.

☐ This location has coaxial cables that enter at ceiling height (15 to 20 feet above ground level), and all equipment grounding is done at floor level or below.

THE NUMBER OF CHECKS ABOVE THAT APPLY INDICATES YOUR EQUIPMENT AND PERSONNEL RISK:

<table>
<thead>
<tr>
<th>Number of Checks</th>
<th>Risk Level</th>
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<tbody>
<tr>
<td>2 or less</td>
<td>Low</td>
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<tr>
<td>3 to 5</td>
<td>Moderate</td>
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<tr>
<td>6 to 8</td>
<td>Severe</td>
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<td>9 or more</td>
<td>Critical</td>
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WHAT CAN A PUBLIC ENTITY DO TO REDUCE THE POTENTIAL FOR LIGHTNING DAMAGING YOUR EQUIPMENT?

- Keep trees and vegetation trimmed away from electrical lines and electrical systems.
- Assure electrical and telecommunications systems are designed and installed to minimize power disruptions.
- Verify that the building's electrical system is properly grounded in accordance with the National Electrical Code.
- All telephone, cable and satellite wires should be bonded to the same grounding point.
- Communications cables should be installed with appropriate separation from power cables or cross them at right angles.
- Make sure telecommunications rooms are wired to minimize electrical disturbances and fitted with electrical equipment, temperature controls and furnishings that dampen the likelihood of disturbances.
- Install appropriate surge suppression devices. Surge suppression devices regulate the voltage supplied to an electric device either by blocking or diverting voltages above a safe threshold to ground.
- Surge suppression devices should be installed in a staged, cascaded or layered manner to divert surges of various strengths at different points within an electrical system.
- Surge suppressors installed at the high exposure service entrances, where power enters the facility, establish the first line of defense against high powered, externally generated surges. These devices will address surges caused by lightning, power company grid switching, power system faults, severe weather, and neighboring facilities.
- The second layer of defense is established by installing surge suppressors at the distribution panel, which distributes power throughout the facility.
- These surge suppressors protect against high to medium surges that may be externally or internally generated.
- Installing devices at branch panels addresses lower level surges generated by a wide variety of load equipment, including lighting control, office equipment and industrial systems.
- The third layer of protection is at the point where individual pieces of equipment are connected to a power circuit or to a telecommunications or data circuit.
- Some equipment and circuits may require special attention. Process control, sensing and monitoring devices may all require individual protection, including plug-in units installed at point-of-use locations.
- Telecommunication and data circuits are extremely vulnerable to relatively low-level surges and need to be protected at the point of entry.
- There are several manufacturers of surge suppression devices which are designed to meet a variety of circumstances and conform to well-developed specifications, guidelines and standards.
- Selecting the appropriate devices to meet your needs obviously depends on performance criteria. Experts, however, emphasize that installation and inspection requirements for devices that fit the business' environment are among the most important factors in selecting appropriate surge protection.
- While surge suppression devices are the major tool minimizing surge damage, they cannot prevent damage caused by direct lightning strikes, nor the rarely occurring temporary over-volts cause by severe faults in power company cables.
- Install an Uninterruptible Power Supply (UPS) for computer equipment: UPS is an electrical apparatus that provides emergency power when an input power source fails. This device differs from an emergency power system or standby generator in that it provides near-instantaneous protection from input power interruptions for a relatively short period to allow time to properly shut down protected equipment or bring an auxiliary power source on line. Installing such a device for computers, data centers, telecommunications equipment or other electrical equipment could help avoid an unexpected power disruption that may lead to injuries, fatalities, serious business disruption or data loss.
- If your building is provided with a lightning protection system, it is important to make sure that the exposed elements of the system are adequately anchored to the structure. In the aftermath of high winds, it is not unusual to find that cables and components of the system have broken loose from their anchorage points. The movement and impact of the lightning protection components especially on membrane roofs can lead to holes and cuts in the roof surface that then could lead to water leaks.
- Check to make sure that any maintenance staff and/or contractors working on the building do not inadvertently remove or disengage any components of your lighting protection system, while performing routine maintenance or repairs.
RECOMMENDED GUIDE FOR THE PROTECTION OF EQUIPMENT & PERSONNEL FROM LIGHTNING

This document covers: protection methods for Ground Potential Rise (GPR), isolation, shielding, and grounding from lightning. **Warning:** Protecting a structure from lightning does absolutely nothing to protect the equipment within that structure and in some cases the housed equipment can be worth more than the value of the structure.

Lightning damage to equipment results in losses exceeding twenty-six billion dollars annually in North America, and nearly three times that worldwide with more than 150 strikes per second. Insurance payments resulting from lightning damage, accounts for approximately 6.5% of all property and casualty claims. Ironically lightning damage to equipment can be reduced or prevented.

Special protection methods to prevent lightning damage can be very simple, are reliable, and inexpensive, particularly when compared to the cost of equipment repair and replacement, as well as the possible consequences of harm to personnel. However, methods for lightning protection cannot be found in the code books, i.e.; National Electrical Code (NEC) or the National Electrical Safety Code (NESC). Per the scopes of these two well known codes, lightning is not covered whatsoever, yet they are relied upon for practically all general construction in the United States.

Don’t expect the Lightning Protection Standard (NFPA 780) to provide guidance either, for the prevention of lightning damage to equipment. It is not within the scope of this document either. The scope if this document covers the protection of structures only.

Thus, documented methods for the special protection of equipment from lightning cannot be found in the two main codes or the Lightning Protection Standard that are systematically referred to for practically all general construction in the United States. This is in part the reason why there is so much needless lightning damage. This guide is dedicated to providing special lightning protection methods for **equipment.**
1. Scope

This document presents recommended engineering design practices for the prevention of lightning damage to **equipment** within buildings. It follows that if equipment is protected from damage by lightning, then personnel using or associated with the equipment will also be protected. Protection of maintenance personnel is not covered in this guide. The following topics are included in this document:

1) Lightning grounded towers, buildings, equipment.

2) Divide and control lightning strike energy.

3) Tower location in respect to equipment building, electromagnetic radiation, need for Faraday Cage.

4) Coordinate the coax cable entry with building equipment grounding.

5) Voltage divider circuit from lightning traveling down a tower.

6) Lightning-A major source of Ground Potential Rise.

7) Bulkhead or wave guide hatch.

8) Single point ground location.

9) Isolate wire-line communications from remote ground.

10) AC power surge protection and UPS at the power entrance facility.

11) Standard telephone pair protection is worthless in a GPR.

2. Introduction

Electrical equipment damage from lightning may be placed into two major categories: (1) improper or insufficient grounding, and (2) no special protection from ground potential rise (GPR). Improper or insufficient grounding will result in the equipment being stressed and or damaged (potential difference) from nearby equipment, metal objects, misdirected current flow, etc. No special protection from a GPR will result in the equipment being stressed from its attachment to a remote ground at some distant location through communication wire-lines or power supply wiring.

Standard protection, in the industry, for the termination of communication wire-line services is gas tubes. Gas tubes are shunting devices and can be found on virtually every telephone pair terminated in homes, buildings, etc., in the country. They are designed to shunt (connect to ground) "incoming energy" and protect equipment and personnel from harm.
However, no shunting device ever made will protect electronic equipment from a GPR or "outgoing energy", whether induced from lightning or from a faulted power line. Shunting devices which are now connected to an elevated ground (outgoing energy) during a GPR, merely offer an additional current path off the site to remote ground (the other end). Thus, these devices guarantee a connection of the communication path in the reverse direction from which they were intended to operate if there is a GPR.

This single fact (outgoing energy from a GPR) places most telephone and power installations in danger of equipment damage and personnel harm from lightning. One of the most dangerous locations to personnel is the 911 center. The typical 911 center is a relatively small building beneath a very large radio tower. This tall tower is for the dispatch of emergency services and is also a very likely target for lightning. Personnel taking emergency calls coming into the center must be at the phones at all times and do not have the luxury of remaining off the phone during lightning storms, as recommended in virtually every telephone book in the country.

Whether it is a 911 center or a cellular telephone antenna on top of a hillside, special protection methods are available to prevent lightning damage to equipment and associated working personnel. Methods will be presented to enable engineers to incorporate them into the general construction design.

### 3. Definitions

1) Lightning: A current of approximately 30kA (50% probability), that has an approximate frequency range from dc to 1MHz, with a minimum current value of approximately 9kA and a maximum current value of approximately 400kA.

2) Ground Potential Rise (GPR): The voltage that develops on a grounding system from electrical current flowing through the impedance of that grounding system. One source of this current is from lightning discharging down into the grounding system.

3) Lightning GPR: A minimum voltage of approximately 7.5kV in the earth at the point of a 30kA lightning strike.

4) Ground Grid or Ground Ring: The grounding system built under a building, antenna site, etc., in which all metallic equipment, plant structures and hardware are bonded.

5) Remote Ground: The distant end of a wire-line communication circuit that is at a different ground reference with respect to the near end.

6) High Voltage Interface (HVI): The physical separation and isolation of wire-line communication's conducting paths using optical isolation or magnetic coupling.
4. Lightning-A Major Source of Ground Potential Rise

There is a 50% probability that a lightning strike will be approximately 30kA. If the self-
inductance of the earth is estimated very conservatively at .5x10^-6H, and lightning takes the form
of a pulse which has a typical rise time of 2x10^-6S, then from V=Ldi/dt; the estimated GPR of a
30kA strike will be 7.5kV. Values of GPR could easily triple for higher current lightning strikes
or strikes passing through higher inductance.

If the inductance of a grounding system is 10^-6H, then a GPR of 15kV may result on a grounding
system from a 30kA lightning strike. Thus, any grounded equipment that is connected to wire-
line communication pairs is in jeopardy from outgoing currents seeking remote ground.

If we are considering a very large structure with many (1000+) communication pairs, such as a
central office, the effect will be greatly reduced with the many multiple paths to remote ground,
because of current division. However, if we are considering a small structure with relatively few
communication pairs to remote ground then we must consider isolating all wire-line conducting
paths.

As discussed in the introduction, gas tubes, MOV's, SCR's, SAS's, etc. are ground shunting
devices and thus, will not protect equipment from a GPR. Also, the firing speed of these devices
is of no consequence. These devices merely offer an additional path to remote ground through
the communication pairs for any and all outgoing currents. In fact, they guarantee a connection
to the communication path in the reverse direction from which they were intended to operate!

The only GPR solution for protecting equipment connected to wire-line communications is
through isolation, using optical isolators or isolation transformers. These devices isolate and thus
prevent current flow. If there is no path for outgoing currents to flow, there will be no current
flow. If there is no current flow there will be no harm to equipment or associated working
personnel.

5. Divide and Control

The control of dissipating lightning strike energy requires division. This is an absolute must for
success, because of the magnitude of the current and the resulting surge impedance of any single
dissipation path. Ten radials connected to a ground ring bonded to an antenna, will divide
lightning current up into ten smaller segments. This will help insure that the lightning will more
likely follow the designated paths for dissipation into the earth and lower the resulting GPR to
the adjacent equipment building grounding system.

The optimum length of these ten radials is approximately 80 feet each with interconnecting 10
foot ground rods, spaced every 20 feet. Longer length radials will offer little dissipation
improvement, because the lightning strike energy will not remain on the radials for much over 80
feet. In very limited spaces, the recommended minimum grounding system is at least 200 feet of
buried bare ground conducting wire composed of five radials, each 40 feet in length, with
interconnecting 10 foot ground rods, spaced every 20 feet.
A greatly improved copper wire grounding system can be easily achieved by the use of conducting cement placed around the radials at the time of installation. The cement will harden into concrete both protecting the grounding system (giving it many years of additional life), and making the system a much better (lower) ground resistance.

6. Tower Location

Design engineers attempting to keep transmission loss low along with the real-estate issues usually dictate that the associated equipment building be as close to the antenna tower as possible. This current practice couldn’t be more wrong in the design of a reliable and robust equipment system to lightning.

First, equipment buildings associated with nearby antenna towers must be far enough away (thirty feet minimum) to minimize the magnetic field associated with lightning and the resulting (microwave oven) damage to equipment circuits. Magnetic field strength drops off as the square of the distance. If the real-estate prohibits the building from being more than thirty feet from its antenna tower, consideration must be given to engineering a Faraday cage (wire mesh) around the interior of the building. Without a Faraday cage, equipment damage cannot be prevented no matter how well the equipment is grounded or isolated from remote ground.

Second, equipment buildings associated with nearby tower antennas must also be far enough away (thirty feet minimum) to keep the lightning GPR at the tower base from saturating the building grounding system, before a majority of it can be dissipated. These two grounding systems must be bonded together at one single point. However, a bond of thirty feet or more will significantly reduce the resulting GPR at the equipment building due to the impedance of this lengthy bond. This is one of those rare exceptions in which a lengthy bond is an advantage in supporting a robust grounding system to lightning.

7. Single Point Grounding

Single point grounding (ground window) is an absolute must to prevent equipment damage from lightning. Single point grounding is an absolute must, because the resulting GPR from lightning is a wave of voltage rise, or energy surge that passes through a grounding system. This demands that all equipment be bonded to the grounding system, at one location (single point), to insure that every metallic object rises and falls in potential together.

Personnel working at equipment that is susceptible to GPR must be protected by a single point grounding system to guarantee that they are out of harms way to different equipment’s potentials. This is also known as touch potential.

8. Bulkhead Panel or Waveguide Hatch

The ground window where coax cables, waveguide, antenna wires, etc. penetrate the wall of the equipment building is called a bulkhead panel or waveguide hatch, and is an absolute must to prevent equipment damage from lightning. The bulkhead is made out of solid copper. The
installation and proper engineering design of the bulkhead will insure that lightning does not enter the equipment building on any entrance cables coming from the antenna tower.

The bulkhead must be bonded to the building grounding system at the single point grounding location. This is also the same single point ground where the tower grounding system is bonded to the building grounding system.

The height above ground that the tower cables pass into the building through the bulkhead is comparable to a voltage divider circuit. The approximate voltage over the height of a tower struck by lightning is approximately 250kV. Thus, at one tenth the tower height, the voltage on the tower cables will be 25kV.

The best entrance location for the bulkhead is at tower base level to insure the lowest level of voltage on the entrance cables. This cable entrance at ground level also enables all equipment in the building to be grounded at the base or floor level. This results in minimum equipment voltage stress and maximum safety to personnel.

If the bulkhead is engineered high above tower base (15 to 20 feet), then all equipment grounding within the building must be made at this height. Thus, equipment racks must be isolated from the floor and grounded at ceiling (bulkhead) level to prevent lightning current from passing through the equipment in order to get to ground. Grounding of the bulkhead to building ground requires wide copper strap.

9. Isolate Wire-Line Communications

A lightning strike to a grounding system produces an elevated ground or GPR. Any equipment bonded to this grounding system, and also connected to wire-line communications, will most likely be damaged from outgoing current seeking remote ground. Personnel working at this equipment are susceptible to harm, because they will be in the current path of this outgoing current.

The equipment damage from a lightning strike may not be immediate. Sometimes equipment is weakened by stress and primed for failure at some future time. This is called latent damage and leads to premature ‘mean time before failure’ (MTBF) of the equipment.

The best engineering design is the use of all dielectric fiber optic cable for all communications. Obviously, a fiber optic cable is non-conductive, provided that it is an all dielectric cable with no metallic strength members or shield, and isolation is no longer a requirement. This is obviously because physical isolation is inherent in the fiber optic product itself. This all dielectric fiber optic cable must be placed in PVC conduit to protect it from rodents.

However, in these tough economic times, most budgets cannot afford fiber optic cables, so the engineering design solution to protect this equipment is to isolate the wire-line communications from remote ground. This is accomplished using optical isolators and or isolation transformers. This equipment is housed together, mounted on a non-conducting surface in a non-conducting cabinet, and is called the High Voltage Interface (HVI).
The HVI isolates the equipment during a GPR and prevents any current flow from a higher potential grounding system to a lower potential grounding system. This totally protects any equipment from damage or associated working personnel from harm.

As mentioned in the introduction, no grounding shunting device ever made, no matter how fast acting, will ever protect equipment from a GPR. Ground shunting devices are connected to the elevated ground during a GPR, and offer an additional current path in the reverse direction from which they were intended to operate. Obviously, this flow of current, even away from the equipment, will immediately cause equipment damage and harm to working personnel.

10. AC Power Surge Protection

The building AC power supply is also susceptible to the effects of a GPR. Since the neutral and ground wire of a power entrance facility must be bonded (by code) to building ground, a rise in potential of the grounding system will place a surge on the neutral and ground wire. This surge will radiate, not only throughout the building, but also away from the building on the incoming power cables. In some cases, the elevated potential of the neutral and ground wire may actually be greater than the potential of the power (phase) wires.

The resulting surge on the power wires may damage building equipment power supplies, other powered equipment parts, or weaken equipment parts for future failure. This is known as latent damage. However, the facility entrance power supply is much more robust a system than the communications system, and its protection using a shunting system is very effective (in most situations) in protecting the associated building equipment. Obviously, the best protection would be to power the building with fiber optic cables, but that technology is not here yet, so second best (a shunting device) will have to do.

In addition to a protected power entrance facility, there may also be the need to protect secondary power panels throughout the building. This is to minimize the magnitude of the power surge that may get past the main power panel.