

# Lightning Protection Guidelines for Equipment Connected to an Antenna Feeder Cable or Waveguide

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The coaxial antenna feeder cable or waveguide is the primary source of damaging lightning energy to equipment at a communications site. When struck by lightning, the tower acts like a voltage divider. For a few nanoseconds, there will be a high peak voltage at the top referenced to zero voltage at the base. Current will then flow through the tower and all attached conductors. See **Figure 1**.

If the bottom coaxial cable/waveguide ground kit is at any elevation above the earth, the overall inductance to earth of the tower below the ground kit, the series inductance of paralleled coaxial cables/waveguides to the building, and the paralleled entry panel ground conductors can be high enough to cause a substantial inductive voltage drop. The resulting voltage on the coax shield/waveguide will drive current to the equipment where other I/Os and the electrical safety ground can provide a path to ground through the equipment chassis.

The best way to prevent lightning caused coaxial shield currents from reaching equipment is to minimize the peak voltage at the building entry panel. See **Figure 2**. This may be accomplished by installing, on the inside of the building, a continuous conductive ground plane bonded to the building ground system. The large surface area ground plane is necessary to provide a low inductance path to ground for the entry panel's lightning surge current, as well as provide for the high frequency component to minimize the resulting inductive voltage drop. Each coax cable/waveguide is attached to the panel with a grounded protector/feed

The recommended entry system would provide a con-

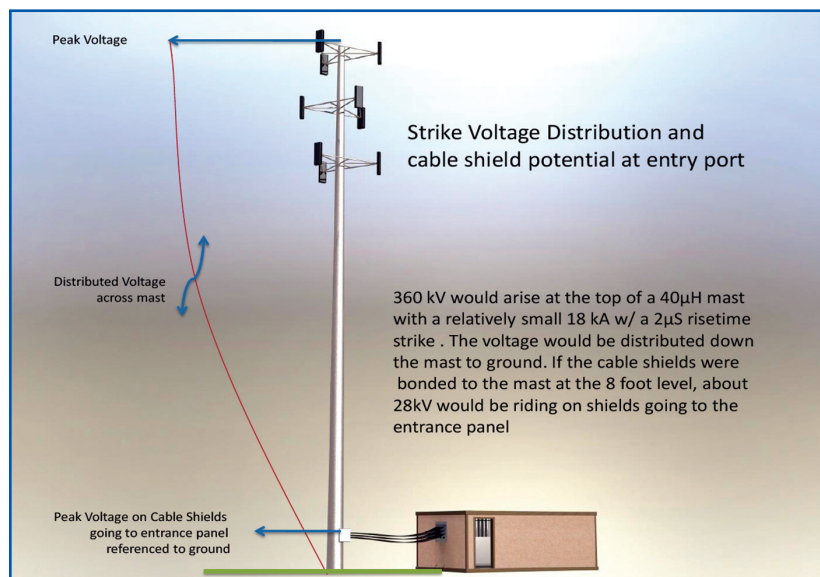


Figure 1

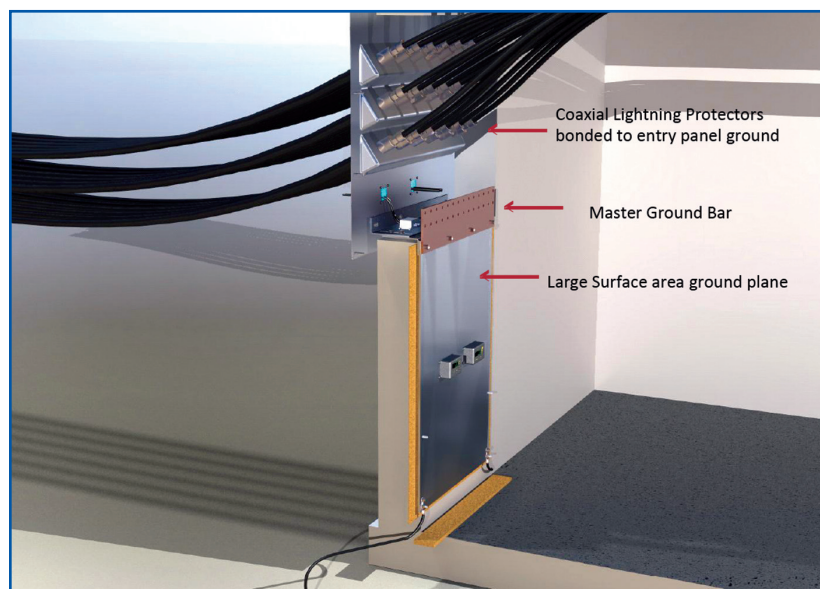


Figure 2

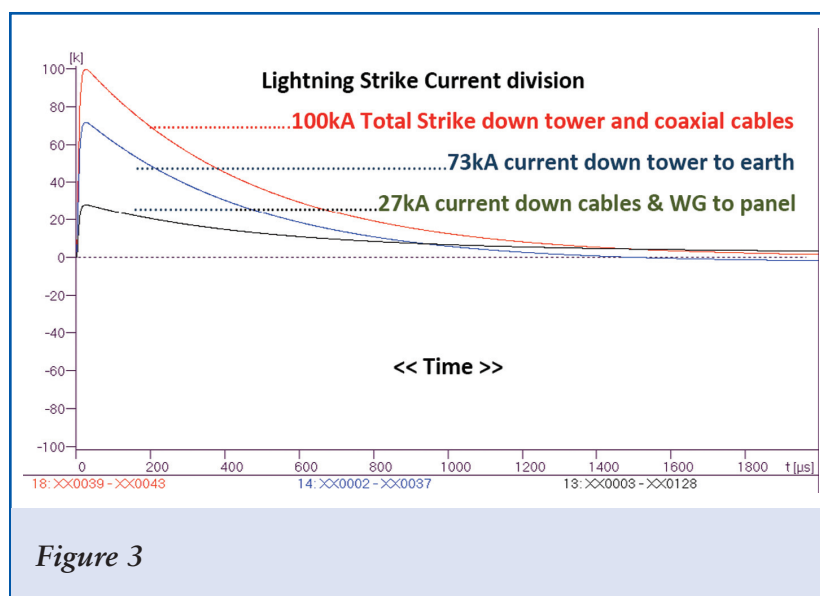


Figure 3

tinuous surface area “single point ground” plane from the coaxial cable/waveguide entry to the building ground system.

A continuous surface area ground plane:

- keeps inductance low with no mutual coupling (as with

parallel ground straps)

- minimizes inductive voltage drop during lightning event
- improves MGB (Master Ground Bar) performance
- provides a low impedance single point ground return path for lightning transients

The concept drawing illustrates this principle:

In a 100 kA strike computer simulation, the amount of strike current delivered to the entry plate is determined by:

- the tower's inductance to earth below where the coaxial cables are bonded to the tower and turned toward the entry panel
- the inductance of the paralleled coaxial cables directed to the entry panel
- the inductance/impedance of the entry port/master ground bar to ground at lightning transient frequencies

The amount of current on each of the (same sized) coaxial cables would be determined by the peak current on all coaxial cables at the elevated coaxial cable shield / tower ground connection, divided by the number of equal sized coaxial cables directed to the entry panel. See **Figure 3**.

Most of the lightning energy goes down the tower to earth, with current divided between the tower ground and entry panel ground system. If coaxial cables/waveguides on the tower were turned towards the entry panel at a lower point on the tower, and shields were bonded to the tower, less potential and current flow would be applied to the entry panel/master ground bar. Always direct cables to the entry panel at the lowest practical location on the tower.

The 27 kA on the feeder cables divided by the 18 coaxial cables shown in the concept drawing equal 1.5 kA per

cable. A 7/16 DIN connector body could handle the coaxial cable shield current to ground and eliminate the requirement for shield grounding kits and an outside master ground bar.

Isolate the “ice bridge”/cable tray structure from the entry panel. Only coaxial cables, DC power (if required), data cables, and tower light wiring should complete the circuit between the tower and entry panel.

**Why are Coaxial Cable Lightning Protectors Required?**

During a strike, a difference in potential arises between the coaxial cable shield and the center conductor at the equipment end of the cable. A coaxial cable will transfer RF energy efficiently from point A to point B with minimum losses at the operating frequency. But as the cable length is extended, it attenuates higher frequencies according to the manufacturer’s specifications per unit length. The cable, in effect, becomes a low pass filter.

There is another factor called “velocity of propagation.” This term defines how fast, as a percentage of the speed of light (s.o.l.), an RF signal will propagate through a conductor. Typical specifications might be 98% s.o.l. for the cable shield, and 88% s.o.l. for the center conductor. These percentages are logically called Velocity factor ( $V_p$ ). An analysis of all the parameters involved is beyond the scope of this article, but can be understood with the graph in **Figure 4**.

When lightning strikes the tower, the shield and center conductor at the antenna are simultaneously elevated in potential. Since there is more surface area on the shield (lower L), the propagation velocity will be faster, and high frequencies will not be as attenuated as on the slower propagating center conductor. This difference in propagation time and high frequency roll off of the fast lightning pulse creates the voltage differential and subsequent damaging current flow through equipment.

A coaxial cable lightning protector equalizes the elevated potential on the shield with the yet to be elevated potential on the center conductor. It reduces the potential on the elevated shield (with a proper ground connection), causing reduced current flow through the equipment chassis. The protector applies the remaining shield potential to the yet to be elevated coaxial cable center conductor through a gas tube or appropriate mechanical RF isolation device.

If the shield/chassis and coaxial cable center conductor are immediately brought to the same potential across the equipment’s input circuit, little or no current will flow through the equipment input due to propagation caused delayed center conductor current. A “filter type” protector adds a mechanical DC blocking device (“capacitor”) to the center conductor on the protected side to further reduce energy throughput to the equipment. The Applications Overview in **Figure 5** describes typical usage.

**Are Lightning Protectors Required for Waveguide?**

Probably not. The EW (elliptical waveguide), the EW flange to coax adapters, and the probability of coupling fast rise time lightning strike energy, additive to the TE (transverse electric) or TM (transverse magnetic) wave in the EW to a coax cable center conductor is almost zero. The principles discussed here are equally applicable to rectangular, rigid, flanged waveguide.

Although the DC component of a lightning strike will flow throughout the EW’s conductive cross section, lightning’s fast transient surge current on the EW will ride mostly on its outer surface. The EW is usually bonded to the grounded tower where it turns to the entry panel from the tower, and again at the grounded entry panel as it enters the equipment building. Most of the DC current will be removed by the time it enters the building by

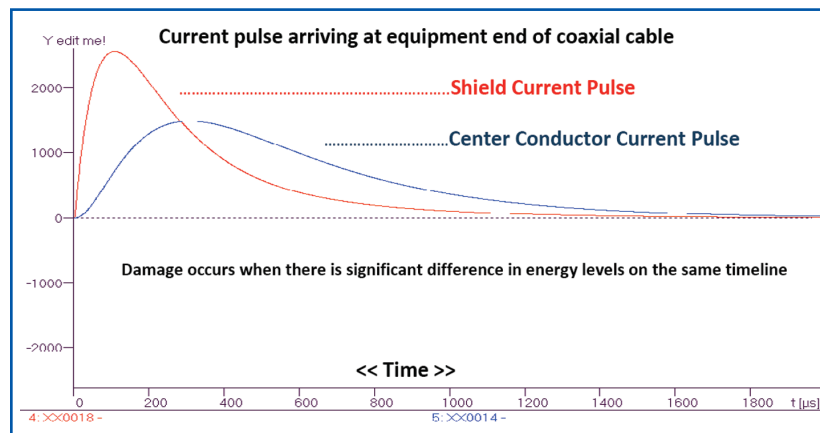


Figure 4

**Applications overview**



DC blocked isolation of antenna and equipment ports for superior surge performance. This design will not pass through a voltage on the center pin.



DC pass design for applications requiring power to be supplied to Tower Top mounted equipment. Selection of RF Power and DC Voltage is critical to ensure proper operation.



DC blocked single transmitter design for 20 -1000MHz non-combining applications. The RF power rating is reduced as the operating frequency increases (see specifications).



Figure 5

ground bonds applied at the tower and entry panel.

The remaining high potential on the EW is usually caused by the inductive voltage drop from lightning transients across the lower tower section and the entry panel ground conductors to the perimeter ground.

If the equipment racks have grounding conductors at the top routed to the entry panel single point ground, and are insulated from conductive flooring, there should be no significant continuing current flow through the EW to the rack. Although the EW transition coax jumpers to the equipment input in the rack provide a conductive path from the elevated potential EW, they are also in parallel with the top grounding conductors, and once the rack’s capacitance is charged through the EW and grounding conductors, current flow through the jumpers and ground conductors should stop.

A coaxial lightning protector is designed to limit center con-

ductor throughput energy and equalize the shield to center conductor potential differential developed across the typical radio equipment antenna input/output due to impedance differences between shield and center conductors (e.g. “unbalanced coax”) when a fast rise time, high current pulse transverses both the coax shield and center conductor.

An EW can transfer standing electrical (or magnetic) wave energy to a solid conductor (such as a coax cable center conductor) using a probe inserted at a precise location in the EW (usually at maximum standing waves, depending on the freq/mode in the waveguide). A 90 degree perpendicular probe [TE] is usually a voltage fed/excited open circuit, and length is usually an even fraction or multiple of the operating wavelength.

Since the “probe” inside the terminating section of waveguide is open circuit with a small capture area, a magnetic



field from current flow on the waveguide (TM mode) should not transfer energy to the (TE mode) center conductor. There would be no current pulse on the center conductor other than induced energy from the short coax cable jumper to the equipment.

Unless the jumper is very long (greater than 3 meters?), the equipment input is very sensitive to spikes (call the manufacturer), or you get a very high current multiple stroke lightning event (unlikely), using a coaxial protector at the equipment I/O on the jumper from EW to equipment is optional.

### It All Gets Down to This!

All the bonding and protectors in the world will not protect equipment unless there is an adequate lightning ground system installed beneath them. A lightning ground system at a communications site should be capable of dispersing large amounts of electrons from a strike over a wide area with minimum ground potential rise (GPR). GPR means any difference in voltage within the strike's local sphere of influence (step potential). The lightning ground system should be capable of doing this very quickly (fast transient response). By spreading electrons out over a wide area very quickly, the

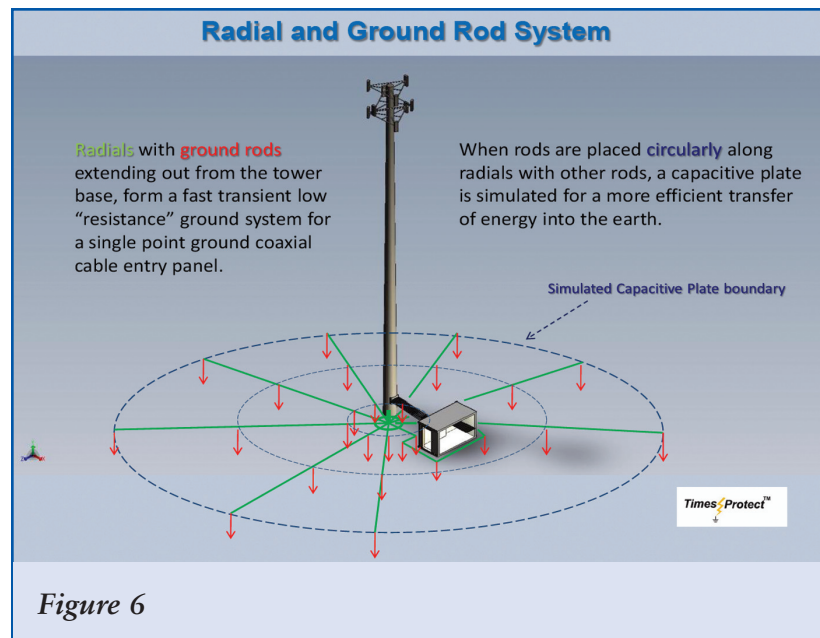


Figure 6

step potential for any smaller given area would be reduced. See Figure 6.

The speed, or transient response, of the ground system would be dependent on the geometry and combined inductance of the below grade conductive components, and the resistivity/conductivity of the soil "shunting" those components. The lower the inductance of the system components and soil resistivity, the lower the impedance at higher frequencies, the faster the ground system could disperse electrons. A lightning ground system is an excellent AC power ground. An approved AC power ground might not be a good lightning ground.

Strike energy to the tower

base, and energy through the coaxial cable shields/waveguide directed to the entry panel ground can quickly saturate a ground system and elevate potential throughout the site referenced to the "outside" world. Power lines, telephone, data, control, and alarms all represent a path to a lower potential for incoming strike energy from the tower. Unfortunately, valuable equipment might be in between the strike energy and the lower potential. Properly rated lightning protectors should be installed at each I/O of the equipment at risk.

Consider the lightning grounding system as an RF circuit. Ground rods have a series inductance bridged by earth's

resistance. Connecting ground rods along buried conductors (radials) presents a series inductance (bridged by earth resistance) with additional ground rods along the radial's length.

The additional ground rods (inductance) can be considered in parallel, all bridged by earth's resistance. Multiple radials with ground rods are all electrically in parallel to further reduce inductance. Multiple buried conductors (radials and rods) with attention to geometry and materials will net a good reading on a ground resistance tester and have an enhanced transient response as well.

One or two ground rods for a residence, a ground loop around a commercial building, or a loop and three ground rods around the base of a communications tower might meet code, but will not disperse the strike energy quickly enough to keep the GPR low. Effort and money spent up front on proper grounding will reduce downtime and equipment damage. If attention is not given to grounding, it's a save now, pay (more) later situation.

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