Equipment Rack Grounding

Technical Note

PolyPhaser®

Equipment Rack Grounding

Equipment racks and cabinets can provide an unwanted path for lightning surge energy. The common practice of bringing the antenna cable into the top of the cabinet and securing (bolting) the cabinet to the floor could damage the equipment.

Concrete floors, particularly those at grade level, can provide a conductive path to earth ground during the strike event. Any surge energy arriving on the coaxial cable, power and control wiring, or inadequate equipment ground system could find a lower inductance path to ground through your equipment and conductive concrete floor.

Your first line of defense is on the outside of the building. The value of a good tower ground/radial system (5 ohms or less) cannot be over emphasized. Most of the surge energy from a tower strike event is dispersed away from the building and equipment by the tower ground system. The remaining energy on the coaxial cable shield and center conductor can be directed safely to earth by using a PolyPhaser entrance bulkhead and proper coaxial protector. The entrance bulkhead provides a single point low inductance connection to the building's perimeter ground and the tower radial system.

Your second line of defense is inside the building. Connect all overhead cable trays and equipment ground conductors back to the entrance bulkhead creating a single point ground system. AC power line protectors and control/data line protectors are connected to the single point ground to complete your defensive strategy.

A lightning strike is a series of fast rise time "pulses" that become a constant current source once the path to ground is established. A typical pulse has a rise time of 2us to 90% of peak and a 10 to 40us decay time (to the 50% level). Three pulses per event is the median. The average current is about 18,000 amps for the first pulse, then dropping to half that value for the second and third pulses. Ten percent of all strikes could exceed 60,000 amps on the first pulse and one percent could exceed 120,000 amps. For the following discussion, a 2us by 18kA negative strike pulse will be considered.

When lightning strikes, a tremendous rush of electrons move down the tower and out into the ground/radial system. Since we are dealing with a fast rise time event, the inductance of the tower and paralleled coaxial cables become the primary factor in determining the amount of instantaneous peak voltage developed between the strike point and the bottom of the tower.

The peak voltage drop can be calculated from the formula: $E = L\,di/dt$; where L is the total inductance of path (tower and coaxial cables in uH); di is 18,000 amps (average strike current, abbreviated 18kA); and dt is 2us (rise time).

When the coaxial cable leaves the tower at any elevation above grade level, a voltage divider is created at the take-off point to ground. The divided current, conducted by the coaxial cables towards the building, places the equipment in series with the energy path if the bottom of the rack is grounded.

Lets look at a practical example of a typical cell site installation, consisting of a 150 foot [45.72 M] by 35 inch [889 mm] triangular tower and three 1-5/8 inch [41.3 mm] coaxial cables. The tower and coax cables would have a combined inductance of approximately 15uH assuming that the cables ran from top of the tower to the grade level ground. During a typical 18kA strike event, a 135kV voltage drop would exist between the top of the tower and ground.

Even though the bulkhead entrance panel and appropriate protectors at a single point ground window do their job by conducting shield and center pin energy to ground, equipment damage or interruption may still result since shunt path currents could traverse your equipment cabinet.

In the real world, most coax lines do not run all the way to the bottom of the tower; but usually leave the tower at a convenient height to make an entrance near the ceiling of the equipment room. For example, if the coax lines were to leave the tower at the 10 foot [3.48 M] level, traverse 10 feet horizontally to the equipment building, attach to a ground bar via a ground kit prior to entering the building, and connect to the perimeter/tower ground system with two #6 AWG copper wires, the additional series inductance in parallel with the lower 10 foot section of the tower is calculated as follow:

Three parallel coax lines bent (+90°) leaving the tower. 0.05uH

Three parallel 10 foot lengths of 1 5/8 inch coax. 1.33uH

Ground kit and ground bar bends. 0.3uH

Two #6 AWG copper wires to earth ground. 2.2uH

The inductance of the 10 foot horizontal coax run and ground bar to earth ground is 3.88uH (3.9uH rounded for simplicity). The inductance of the lower 10 foot section of the tower without any coax lines is 2.7uH. When these two parallel inductors to ground are combined (3.9uH and 2.7uH), the lower section of tower has an inductance of 1.6uH.

The following questions may then be answered regarding conditions during the strike event.

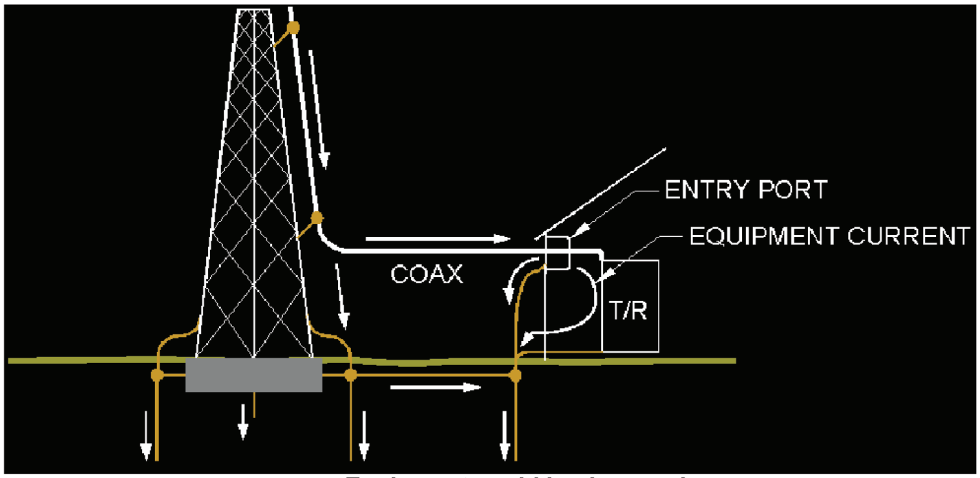
Peak voltage at the 10 foot level on the tower:

E=L di/dt = 14.4kV

Current through the ground bar to ground k(E/L)dt =.... .... .7.385kA

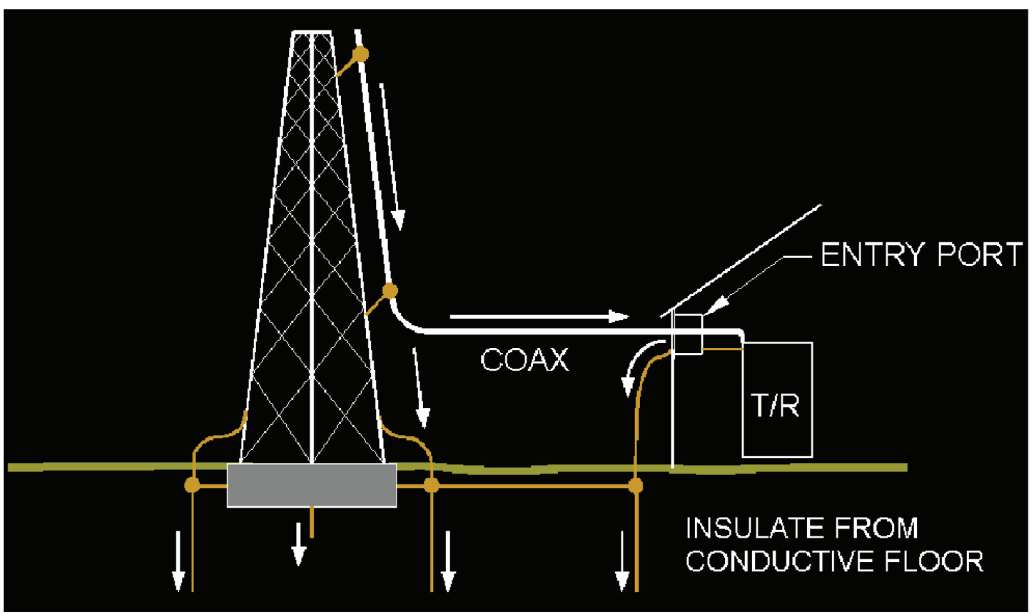
Peak voltage after the ground bar (at the protector):E = L di/dt. 9.231kV

Since the coaxial cable shield is connected to the ground bar via the ground kit, 9.2kV would be present on the shield and will be conducted directly to the antenna connector on your equipment rack. After charging the rack's capacitance, the entire peak voltage would appear at the rack/concrete interface. Depending conductivity of the concrete and rebar placement with respect to the charged rack, 9.2kV could be sufficient voltage to arc through the concrete creating a conductive path and allowing current to flow through the equipment racks.



Equipment could be damaged

The preferable alternative is to allow all racks to rise and fall with the overhead ground system potential without any other paths to ground. For this to happen you must insulate the racks from the conductive flooring.



Equipment Survives

Rack cabinets can act as a “faraday shield” with respect to the components inside by either converting the magnetic field energy into a voltage feeding your single point ground system or as a conductor between the overhead ground system and a conductive floor breakdown path. The breakdown path will produce a large voltage drop and magnetic fields inside the cabinet that are likely to destroy components.

To insulate rack cabinets from a potentially conductive concrete floor some installations place cabinets on wooden platforms. Others use isolation kits for racks that must be physically secured to the floor.

The PolyPhaser Entrance Bulkhead serves as a low inductance entry ground, entry plate, and mounting point for PolyPhaser center pin protectors. Cable trays and system ground wires inside the building should be connected to the bulkhead to provide true “single point” grounding.

If a PolyPhaser Entrance Bulkhead with its two 6 inch [152.4 mm] copper straps were used in the previous example, the inductance path would be lowered to 2.7uH, and the voltage at the entrance bulkhead would be reduced to 5670 volts. With three copper straps the voltage would be even lower. The more surface area to ground the better.

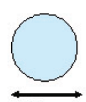
Nothing can stop a lightning strike! How you direct the energy is the difference.

Part 2 Follows Below

Part 2 Multiple straps vs multiple round conductors

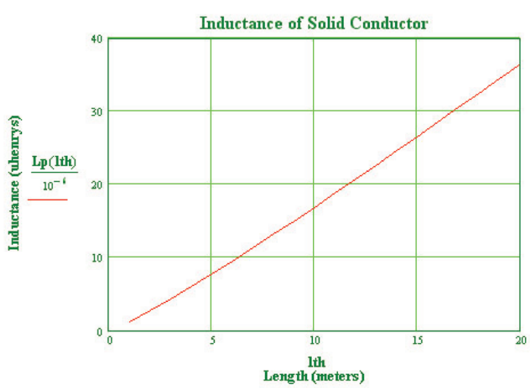
Input Parameters $lth := 1..20$ length of conductor in meters

$rw := 0.0020574$ radius of conductor in meters



Low Frequency Inductance is: (for lth >>rw)

$$Lp(lth) := 2 \cdot 10^{-7} \cdot lth \cdot \left(\ln\left(2 \cdot \frac{lth}{rw}\right) - \frac{3}{4} \right)$$



$Lp(6.096) = 9.677 \times 10^{-6}$

The inductance of a 6AWG wire 20 feet long is 9.677uHenries

$\mathbf{lthstrap} := 0.1 .. 20$ length of copper strap in meters

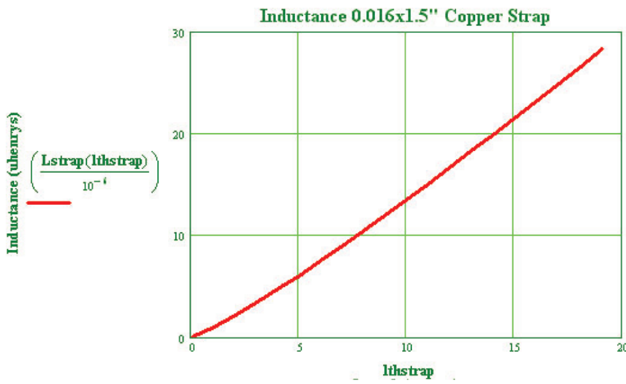
$\mathbf{wstrap} := 0.0381$ width of copper strap in meters 1.5 inchses

$\mathbf{thickstrap} := 0.0004064$ thickness of copper strap in meters (0.016 inches)

$$\mathbf{Lstrap(lthstrap)} := 2 \cdot 10^{-7} \cdot \mathbf{lthstrap} \cdot \left[\ln\left(\left(2 \cdot \frac{\mathbf{lthstrap}}{\mathbf{wstrap} + \mathbf{thickstrap}} \right) \right) + \frac{1}{2} \right]$$

$$\mathbf{Lstrap}(6.096) = 7.63 \times 10^{-6}$$

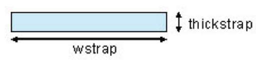
The inductance of a 0.016x1.5" copper strap 20 feet long is 7.63uH.



$\mathbf{lthstrap} := 0.1 .. 20$ length of copper strap in meters

$\mathbf{wstrap} := 0.0762$ width of copper strap in meters 3.5 inchses

$\mathbf{thickstrap} := 0.0004064$ thickness of copper strap in meters (0.016 inches)

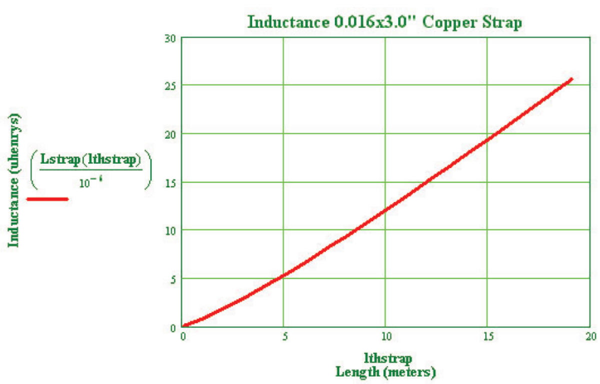


$$\mathbf{Lstrap(lthstrap)} := 2 \cdot 10^{-7} \cdot \mathbf{lthstrap} \cdot \left[\ln\left(\left(2 \cdot \frac{\mathbf{lthstrap}}{\mathbf{wstrap} + \mathbf{thickstrap}} \right) \right) + \frac{1}{2} \right]$$

The inductance of a 0.016x1.5" copper strap 20 feet long is 7.63uH.

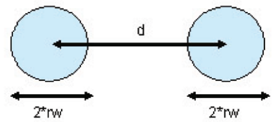
$$\mathbf{Lstrap}(6.096) = 6.79 \times 10^{-6}$$

The inductance of a 0.016x3.0" copper strap 20 feet long is 6.79uH.



Simply increasing grounding strap width does not produce equivalent reductions in Inductance, and thus multiple point grounding straps are preferred.

This is the inductance calculation for 2 round conductors

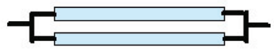


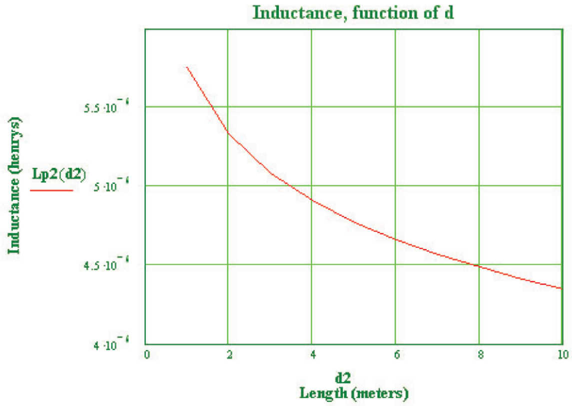
Input Parameters $lth2 := 6.096$ length of conductor in meters

$r2w := 0.002057416$ radius of outer conductor in meters

$d2 := 1 .. 10$

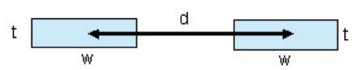
$$Lp2(d2) := 2 \cdot 10^{-7} \cdot lth2 \cdot \left[\ln\left[\frac{(2 \cdot lth2)}{\left(\sqrt{r2w \cdot d2}\right)} \right] - \left(\frac{7}{8}\right) \right]$$





$Lp2(0.3048) = 6.48 \times 10^{-6}$

This is the Mutual inductance calculation for copper straps with a fixed distance



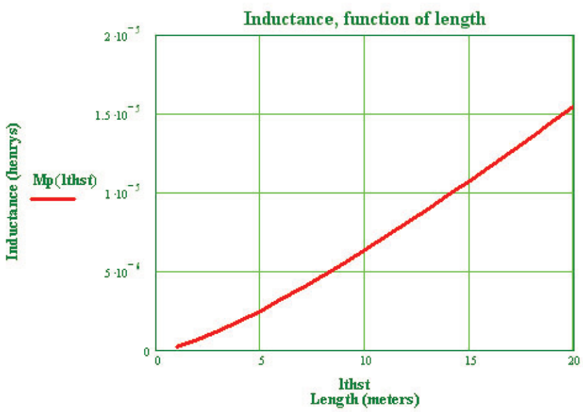
Input Parameters $lthst := 1 .. 20$ length of conductor in meters

$tst := 0.0004064$ thickness of strap in meters

$wst := 0.0381$ width of strap in meters

$dst := 0.3048$ distance between straps in meters

$$Mp(lthst) := 2 \cdot 10^{-7} \cdot lthst \cdot \left(\ln\left(2 \cdot \frac{lthst}{dst}\right) - 1 \right)$$



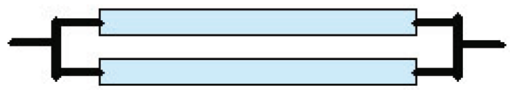
$Mp(6.096) = 3.28 \times 10^{-6}$

Using the single wire inductance and the 2 wire mutual coupling we get:

The equivalent inductance with 2 copper wires in parallel

$L1 := 9.677 \cdot 10^{-6}$ $\quad$ $Mpst := 3.26 \cdot 10^{-6}$

$L2 := L1$



$$Leq := \frac{\left(L1 \cdot L2 - Mpst^2\right)}{L1 + L2 - 2 \cdot Mpst}$$

$$Leq = 6.47 \times 10^{-6}$$

1.5 inch wide copper straps in parallel are lower inductance than the equivalent wires in parallel.

Additional Commentary:

1. Grounding straps have less inductance than wires of equal cross sectional area.

2. Braided copper wire has a much greater potential of being a source of nonliniearities. When wire copper strands oxidize, those strands come in contact with other oxidized strands creating sources of non-linearity.

3. Using multiple grounding conductors (wire or strap) is beneficial in several ways:

a. Reduced DC ground resistance

b. Reduced AC ground impedance

c. Increased reliability