Lightning Protection and Grounding Solutions for Wireless Networks

CPRA
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Few facts about the lightning event

Typically, more than 2,000 thunderstorms are active throughout the world at any given moment producing on the order of 100 flashes per second. As our society becomes more dependent upon computers and information/communications networks, protection from system disruptions becomes essentials.

During fair weather, a potential difference of 200,000 to 500,000 Volts exists between the earth surface and ionosphere. In a lightning event this potential will be responsible for lightning discharge currents of up to 100,000 Ampere.

The average length and duration of each lightning stroke vary, but typically average about 30 microseconds producing average peak power per stroke of about 1 (one) Trillion Watts.

The temperature along the lightning channel (flash) during the electrical discharge is in the order of 20,000 degrees Celsius (three times the temperature of the surface of the Sun)

Wireless networks rely on communication towers for its transmission of Radio Frequency putting them statistically in a very high exposure zone. Average communication site in Florida, during thunderstorm season, will be exposed to 18 to 20 lightning strikes a year.
Aircraft launching step leader
Annual Lightning Flash Rate

High Resolution Full Climatology Annual Flash Rate

Global distribution of lightning April 1995-February 2003 from the combined observations of the NASA OTD (4/95-3/00) and LIS (1/98-2/03) instruments
The lower part of a thundercloud is usually negatively charged. The upward area is usually positively charged. Lightning from the negatively charged area of the cloud generally carries a negative charge to Earth and is called a negative flash. A discharge from a positively-charged area to Earth produces a positive flash.
Step Leader Length is Dependent on Cloud Charge Accumulation

The Larger the Charge, the Larger the Step

Typical Step 150ft. @ 50µS per Step (1µS jump, 49µS pause)

Jumping Hemisphere “Rolling Ball Theory”
Definition of pulse wave-shape

Figure A.1 - Definitions of short stroke parameters (Typically $T_2 < 2$ ms)

- $O_1 =$ virtual origin
- $I =$ peak current
- $T_1 =$ front time
- $T_2 =$ time to half value
350kA
Maximum with 99.5% Confidence level

AND

300kA
Maximum with 98% Confidence level

**Time to Peak Lightning Currents**

Max. $10\mu$-sec
Min. $0.7\mu$-sec

0 to peak current with 96% confidence level

Duration and Amplitude of Continuing Currents

Max. 1000A
Min. 30A

Max. 550m-sec
Min. 35m-sec

Grounding fundamentals for Lightning Protection
Any Conductor is an Inductor!
Inductance considerations – monopole tower

This is the inductance calculation for a round Tubular conductor

**Input Parameters**

- \( l_{th} := 2..100 \) \hspace{1cm} length of conductor in meters
- \( r_{wo} := 0.4445 \) \hspace{1cm} radius of outer conductor in meters
- \( r_{wi} := 0.3937 \) \hspace{1cm} radius of inner conductor in meters

Low Frequency Inductance is: \( \text{(for } l_{th} >> r_{wo} \text{)} \)

\[
L_{ptub}(l_{th}) := 2 \cdot 10^{-7} \cdot l_{th} \left[ \ln \left( \frac{2 \cdot l_{th}}{r_{wo}} \right) - \left( \frac{3}{4} \right) - \left[ 0.028 \cdot \left( \frac{r_{wi}}{r_{wo}} \right) \right] - \left[ 0.38 \cdot \left( \frac{r_{wi}}{r_{wo}} \right)^2 \right] + 0.16 \cdot \left( \frac{r_{wi}}{r_{wo}} \right)^3 \right]
\]

**Inductance of Solid Conductor**

- \( L_{ptub}(50) = 5.412 \times 10^{-5} \)
- \( L_p(50) = 4.666 \times 10^{-5} \)

Tubular Plotted against the solid conductor
360kV would arise at the top of a 40µH mast with a relatively small 18 kA w/ a 2µS risetime strike. The voltage would be distributed down the mast to ground. If the cable shields were bonded to the mast at the 8 foot level, about 28kV would be riding on shields going to the entrance panel.
Lightning current distribution on coaxial cable

Coaxial shield lightning current

Center conductor lightning current
Lightning current sharing between tower and coaxial cables during the lightning event

100kA total discharge current
70kA propagating down the tower
30kA divides itself between distribution coax cables
Why Coaxial Cable Ground Kits are Essential

Inductive voltage drop across entire 40uH tower with 2us rise time and peak current of 18kA  \[ E = -\frac{L}{dt} \frac{di}{dt} \]

Magnetic field coupling into coaxial cable from current flow down the tower can cause a reverse emf on the coax, opposing downward current flow, and creating a differential voltage between tower and coax. Coax cable insulation could breakdown and allow an arc back to the tower.

An additional ground kit at the tower center brings the shield back to tower potential reducing peak voltages and the probability of coax breakdown.
Lightning Protection

“Zone of Protection”

150' Radius
Striking Distance
(100' for flammable liquids)

Per ANSI/NFPA 780

Zone of Protection

Times Protect™
Ground Electrode

Sphere of Influence
Step Potential

Ground Rod

Ground Level

Soil compaction-displacement

Electron Transfer

Times Protect™
Radial and Ground Rod System

Radials with ground rods extending out from the tower base, form a fast transient low “resistance” ground system for a single point ground coaxial cable entry panel.

When rods are placed circularly along radials with other rods, a capacitive plate is simulated for a more efficient transfer of energy into the earth.

Simulated Capacitive Plate boundary
Tower Leg Grounding (UFER vs. AWG #2)
Tower Leg Grounding
Equipment Grounding with Coax Entering from a High Entry Panel

- Grounding at bottom of the rack creates a path for surge current to traverse the rack, upsetting or destroying equipment.

- Proper grounding of the equipment rack. If coax jumper cables enter at the top, ground high. If they enter low, ground low. There will be minimal current flow through the rack.
Rooftop Installations

Water / Sewer Ground

Electrical Ground

Ground Loop / Rods around building

Ground Loop/Rods

GPS Antenna

Cellular Antenna

Lightning Rods (6)

Coaxial Cables from antenna

Perimeter rooftop ground conductors for structural protection system with additional conductors bonding cellular antenna support

Lightning Rod structural protection system down-conductors (4)

Separate ground down–conductor for antenna structure and entry port bond

Equipment ground preferences:
- **Marginal** Bond to structural protection or separate down conductor
- **Good** Bond to structural protection and additional separate down conductor
- **Better** Single bond to structural steel
- **Best** Combine all three methods

Rooftop Ground Considerations

Coaxial Cable Entry panel

Antenna support - entry panel ground bond to building steel

Ground Loop / Rods around building

Electrical Ground

Water / Sewer Ground

Times Protect™
Outside communication shelter copper theft fix

After the fix
Shelter exterior view

Nothing to steal here !!!!!
External view of traditional method and proposed solution

Traditional method consisting of:
- High material and labor cost
- Lack of provisions for other service entries
- Theft exposure
- Very high impedance return path to ground
- High preventative maintenance

Proposed method:
- Addresses theft issue
- Does not require external shield grounding kits
- Makes provisions for Coax/EWG/Data/DC and fiber
- Minimal labor cost
- All prep work performed at the shelter manufacturer
Traditional method:
- Requires separate Inside MGB (IMGB)
- Trapeze or other method to ground SPDs
- Performance affected by long ground wires
- High impedance IMGB ground conductor
- Single point ground by installation
- High ground loop probability

Propose method:
- All RF protectors bulkhead mounted for best surge performance
- Assembly accommodates different wall thickness
- Provisions for grounding of all protectors to the same SPG
- Low impedance ground path for lightning current
- Control of MGB potential rise due to low “L” of assembly
- Accommodates for additional equipment mounting
Ground lead considerations for installation of RF protectors
Applied surge wave-shape 6KV/3KA (8X20us)

Bulkhead mounted SPD without added ground “L”
Surge return directly connected to protector ground
+25.6V, -9.2V

Effects of 1.5 ft ground lead inductance of #1 AWG Cu wire
Voltage and energy throughput drastically increases
+544V, -176V

Note: The length of the grounding conductor connected to any lightning protection device has a major effect on the protector performance as illustrated by the above test. Leadless/Bulkhead installation technique for RF lightning protection devices will eliminate this additive voltage and energy throughput to the protected equipment.
SmartPanel™

Lightning Protectors

Feed-through
LP-FT-DFDF
LP-FT-NFNF

Blank Plug
LP-DP
LP-NP
SmartPanel™

Times Protect™
LP-SP-24N Installed view-metal building
Protector Grounding ???
Images of Lightning damaged RF protector
When everything else fails, there is always plastic tie!
LP-BTR-N Series DC blocked (20-1000MHz)

- DC blocked design
- Multi-strike capability
- Broad band performance up to 1GHz
- Exceptional RF characteristics
- Universal bulkhead and flange mounting
- Elongated Female connectors
- Weatherization gasket included
- Solid Brass design / White Bronze plating
- Phosphor Bronze center pin construction
- Silver plated center pin
- Insertion Loss: < 0.1dB
- Return Loss: <-26dB
- VSWR: <1.1:1
- Energy throughput: <200uJ

LP-BTR-NFF  N Female/Female
LP-BTR-NMP  N Male on Protected
LP-BTR-NMS  N Male on Surge
IP-67 Weatherized LP-BTRW-N Series DC blocked (20-1000MHz)

- DC blocked design
- Multi-strike capability
- Broad band performance up to 1GHz
- Exceptional RF characteristics
- Universal bulkhead and flange mounting
- Elongated Female connectors
- Weatherization gasket included
- Solid Brass design / White Bronze plating
- Phosphor Bronze center pin construction
- Silver plated center pin
- Insertion Loss: < 0.1dB
- Return Loss: <=-26dB
- VSWR: <1.1:1
- Energy throughput: <200uJ
- IP67 Weatherized

LP-BTRW-NFF N Female/Female
LP-BTRW-NMP N Male on Protected
LP-BTRW-NMS N Male on Surge
• Fully weatherized body to IP65
• Broadband RF performance
• Multi-strike capability
• Maintenance free design
• Maximum surge current: 20kA
• Throughput voltage: 2Vpk
• Throughput energy: 150nJ
• Insertion Loss: < -0.2dB
• Return Loss: < -18dB
• RF power: 50Watts
Surge Performance Data for LP-GPX and LP-WBX Series at 6kV/3kA (1.2x50/8x20us) wave-shape

- LP-GPX-05-NFF
- LP-GPX-05-NFM
- Bidirectional operation

- LP-WBX-NFF
- LP-WBX-NMP
- LP-WBX-NMS

User voltage: 5Vdc
Voltage throughput: <12Vpk
Energy throughput: <110uJ

Voltage throughput: <2Vpk
Energy throughput: <150nJ
Energy Throughput

LP-STR and LP-STRL 6kV/3kA
Energy & Voltage Plotted into 50 Ohms with 0.08VDC Offset when applicable

- 50 Ohm Voltage
- Voltage over DC (ABS)
- Energy Over DC Offset

Time

Let-through (Voltage)

Energy Let-thru (joules)
LP-SPT (Surge Protector Tester)

**LP-SPT Specifications:**

- **Dimensions:** 9.0” x 4.0” x 1.5”
- **Weight:** 1 pound
- **Power:** 9V battery, 2 each included
- **Display:** 3.5 digit LCD
- **Test Output:** 1000V / 1mA
- **DUT interfaces:** One type-N female, one type-N male
- **Carrying Case:** Rugged black nylon
- **N–Alligator Clip Adaptor:** Included
Thank you and Questions ???