Lightning Protection and Grounding

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Lightning and EMP

• High Amplitude Pulses (Typically 3 to 4 pulses at 50 mS intervals)
  – Penetrates insulation  \(\gg 10kV\)
  – Induces currents  \(\sim 18kA\)
• Rapid Rise Time
  – 12 uS to 0.25 uS rise times
  – DC to RF  Mostly DC to about 1MHz (but as high as 16 MHz)
  – Rings Resonant Systems (Tuning Fork)
• Covers wide areas  \(\sim 6\) miles wide
• Common Mode and Normal Mode Types
  – Powerline Pulses are generally Normal Mode (one line)
  – Amateur Tower Pulses are generally Common Mode (all conductors)
• Causes Equipment Damage, Can Kill, Can Start Fires, Disrupts Communications
  – 50,000 degrees F
Lightning and EMP Myths

• Destroys all nearby Electronic Equipment!
• Traveled Miles; We cannot Stop it!
• Is attracted to Grounded Objects, so Don’t!
• Damage is avoided by disconnecting cables.
• I am OK, my house is grounded.
• There are tall objects that protect me.
• I worship the god Thor and Valhalla will protect the faithful.
Lightning Facts

• Channel through Air Carries Charge/Current
  – 50,000 ° F
  – Opens at 30 ft / uS  (6 miles / mS)
  – Confined channel heating creates Shock Wave
  – Thunder travels at 1100 ft per second (sea level)

• Strikes Equalize Charge of Cloud to Ground
  – Any Conductor to Ground
    • Metal, Wet Insulators, Bodies of Water, Animals

• Strikes generate tremendous Heat
  – When Jumping Conductors (to lower potential)
    • Responsible for much Mechanical Damage
Lightning Safe Environment
Lightning Safe Environment
What do we do with this?
Lightning Protection

• Redirect
• Modify
• Block and Shunt
  – Redirect
  – Modify
  – Block and Shunt
    • Redirect
    • Modify
    • Block and Shunt.....
Redirection

Spark Gap provides path to Ground.
Coil raises impedance of Ground Path through the Cabinet.
Amateur Redirection
This Doesn’t Apply To Me!

• I disconnect my cables.
• There are taller objects around me.
• It has never hit here before.
• I know of taller towers and they are OK.
• My antenna is fiberglass and insulated.
• My antenna is DC grounded.
• I was wanting to buy a new radio anyway.
1977 Kankakee, IL

• WBØSVY just out of college.
• New Job, New House, New Situation
• Highest Point in Kankakee County
  — Roof Tower, Triband Beam, Long Yagis 2M, 220, 432
  — Towers and Antenna were not Grounded
• July 08, 6:10AM  Direct Lightning Strike
• Damage: Yaesu FT-101, Ham M, Ringo Ranger,
  12VDC Power Supply, Coax Lines, Rotator Cable,
  Microwave Oven, TV, Icom 2M FM
• Action: Stand by the door and watch it burn.
Lightning Entered Home

• Coax Disconnected
• Rotator Cable
  – Ham M Control
    • House Power
      – Yaesu FT-101
      – MicroWave
      – 12 VDC Power Supply
      – TV
      – 2M FM on LV PS

• Lowest Grounding Potentials
  – Gas Line
  – Window Frame
  – Power Ground
Typical Lightning Damage
Lightning Protection

• Redirect
  – Spark Gap, Gas Discharge to Ground System
  – Ground ALL Antenna Support Structures

• Modify
  – LC low pass filter, long coax run

• Block and Shunt
  – Inductor to Ground System for static and pulse
  – Spark Gap to Ground System for pulse and quench
  – Series Cap for RF to block LF and DC pulse
  – Resistor to Ground to protect Equipment
Amateur Redirection
Modify
Coax Cable  Band Pass Filter

- Coax Inductance and Capacitance
  \[ L = 21 \left[ 2.303 \log \left( \frac{41}{d} \right) - 1 + \frac{\mu}{4} + \left( \frac{d}{21} \right) \right] \]
  - 29 pF per foot
- 10 uH per 10 M
- 1000 pf per 10 M
USCG Station Model

These guys go to work during the worst weather and must have reliable communications.
Right Impedance at the Right Place

- Low Impedance to Ground at Antenna Base
- High Inductive Impedance to next stage
- Low Impedance to Ground at Entry
- Low Impedance to Ground for each Radio and piece of Equipment. Single Point Ground.
- High Impedance from Power Line to Ground.
  - Isolated Power prevents damage beyond system.
Ground Systems

Radio

16 ft. 16 ft. 16 ft.

Spacing prevents Current Saturation

Rods Length 8 ft. Station Ground

5/8" Cu Clad Rods CADWeld #2 or #4 Cu Wire Flat Strip?
Ground Improvement

• Moisture
• Conductor Area and Surface Area
• Conductive Additives
  – Carbon (conductor)
  – Calcium Chloride (ions)
  – Sodium Bicarbonate (ions and pH)
  – Bentonite Clay (attracts and holds moisture)
• Low Resistance Bonds (Cadweld)
• Corrosion Resistance
Station Setup

Bonding
All Radio Equipment

I.C.E. coax
Impulse suppressor

ICE or other Surge Supressor

L L L
Impulse Protection

• You cannot stop a large impulse with a single lightning arrestor in most cases.
• You can modify the impulse by lowering its intensity and lengthening its duration.
• Energy is divided and shared by a distributed ground connection.
• You can bond all of your equipment to a good ground so that it acts like a single piece of equipment.
• As with the CG Boat to the right, the impulse of the wave is not going to be stopped, but the boat is designed to ride over the wave.
Impulse Protection 2

• Lightning impulse rings the resonant system.
  – DC to RF high current transients in the system.
• First Defense  Arc Plug and Coax Inductance
  – Inductive Reactance resists RF currents
    • Causes voltage ahead of inductance to rise.
  – Voltage exceeds Arc Plug specification
  – Transient energy shunted to tower and ground.
  – Your goal is to bleed off as much energy as possible.
  – Arc Plugs may overload and fail in a direct strike situation.
  – Coax Shields are Grounded at Tower Base.
Impulse Protection 3

• Attenuated and elongated Common Mode impulse travels on coax.
• Nature of coax further attenuates RF.
• ICE Lightning and Impulse Protector
  – Impulse/static is shunted to ground through inductor.
  – Voltage on line will exceed Arc Plug specification
    • Arc Plug will fire. Inductor magnetic field will collapse.
    • DC portion of impulse blocked by capacitor.
    • Resistor and Arc Plug limit the energy in the capacitor.
    • This cycle may continue several times.
  – Impulse heads to house and ham station.
Impulse Protection 4

• Grounded Switch
  – Attenuated pulse is directly shunted to ground

• Radio Receiver
  – Coax Inductance to entry further inhibits RF current.
  – Pulse enters receiver. This is common mode, so both the inner conductor and outer conductor carry a similar current and phase. Small Differential Voltage.
  – Manageable AC and RF impulse
  – Entire Bonded System becomes elevated in voltage as impulse works against ground impedance.
Impulse Protection 5

• Elevated Voltage on RF Equipment
  – All Equipment electrically bonded to SP Ground.
  – No differential voltages to cause arcing/damage.
  – Isolated Power is not ground referenced.
    • Isolation good to several thousand volts.
  – As ground impedance conducts impulse away, voltage on equipment will decline to normal level.

• Don’t forget about Rotator and Control Lines
Power Line Strike

• Normal Mode Impulse come along Line
• Impulse enters Panel
  – Varistor Whole House Protector shunts to ground
  – Or, Impulse is distributed throughout house
• Impulse hits HR station Isolation Transformer
  – Only LF passes through transformer magnetics
  – Impulse hits Varistor and is shunted to ground.

Warning: Varistors often fail in a Short Condition. You must provide circuit protection between the power and the Varistor or Power Strip. Many Power Strips are wired to protect Common Mode, not Normal Mode.
Strike Modes

Impact on overhead lines

Coupling by radiation

Rise in ground potential

Affected network or equipment
Nice Installation Tower Base
Alpha Delta vs Ind. Comm. Engrs.

Alpha Delta Relies on Coax Inductance to cause voltage to fire Arc Plug. AD provides no protection to a grounded switch or radio front end. AD Arc Plug must drain all the strike energy. Rated about 1W. AD will not drain static electricity from coax. Charge can build.

ICE inductor bleeds static and absorbs impulse. ICE Arc Plug fires to collapse inductor magnetic field. Less Dissipation. ICE Capacitor blocks DC and impedes lower frequencies. ICE Resistor protects radio and provides a path to discharge Capacitor.
Polyphaser vs ICE

Polyphaser relies on Coax Inductance to fire Arc Plug
Polyphaser blocks DC and impedes low frequency impulse.

Many Polyphaser units are narrow band due to Capacitor.

ICE has Inductor to bleed static and absorb an impulse.
ICE uses Arc Plug to collapse Inductor magnetic field. Lower Dissipation.
ICE has resistor at output to bleed voltage from Capacitor and protect Radio.
Power Protection
Lightning Strike Density


Lightning density maps provided by Vaisala-GAI (formerly Global Atmospherics), Tucson, Arizona. Map is for general informational and educational purposes only and is not indicative of current or future lightning activity. Lightning data provided by the U.S. National Lightning Detection Network.®

The 5-year Flash Density Map shows the average amount of lightning recorded in 1996–2000. The average amount of lightning that occurs in any given area varies significantly from year to year, as shown in the annual maps for 1996 and 2000.
Corrosion

• Requires Electrolyte and 2 Conductors
  – Water with contaminants
  – Copper, Zinc, Stainless Steel, Steel, Aluminum
  – Electrical Connection

• Protection
  – Block Electrolyte with Coating (paint, tape, cover)
  – Block Current with Insulator
  – Provide Sacrificial Anode
Galvanic Corrosion

Relative Potentials
Zinc: -0.80 V
Steel: -0.40 V
Stainless: -0.30 V
Copper: +0.00 V
Lead: +0.10 V
Titanium: +0.30 V

Zinc sacrificed to Protect Structure

When grounding a tower with Cu conductor
Use Stainless Steel foil between the Cu and Zn that galvanizes the tower legs.

Otherwise Zn and Steel will be corroded by the Cu electrical connection.

Penetrox is also useful.
### High Corrosion Activity

<table>
<thead>
<tr>
<th>High Corrosion Activity</th>
<th>Low Corrosion Activity</th>
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<tbody>
<tr>
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<td>Copper (CA102)</td>
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<tr>
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<td>Aluminum 2017, 2024, 2117</td>
<td>Cupro Nickel 80-20</td>
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<tr>
<td>Mild Steel 1018, Wrought Iron</td>
<td>430 Stainless (passive)</td>
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<tr>
<td>HSLA Steel, Cast Iron</td>
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<tr>
<td>Chrome Iron (active)</td>
<td>Nickel Aluminum Bronze (CA630, 632)</td>
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<tr>
<td>430 Stainless (active)</td>
<td>Monel 400, K500</td>
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<tr>
<td>302, 303, 321, 347, 410, 416 Stainless Steel(active)</td>
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<tr>
<td>316, 317 Stainless (active)</td>
<td>60% Ni 15% Cr (passive)</td>
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<tr>
<td>Carpenter 20Cb-3 Stainless (active)</td>
<td>Inconel 600 (passive)</td>
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<tr>
<td>Aluminum Bronze (CA687)</td>
<td>80% Ni 20% Cr (passive)</td>
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<tr>
<td>Hastelloy C(active)</td>
<td>Chrome Iron (passive)</td>
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<tr>
<td>Inconel 625(active)</td>
<td>302, 303, 304, 321, 347 Stainless (passive)</td>
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<tr>
<td>Titanium(active)</td>
<td>316, 317 Stainless (active)</td>
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<tr>
<td>Lead/Tin Solder</td>
<td>Carpenter 20Cb-3 Stainless (passive), Incoloy 825 (passive)</td>
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<tr>
<td>Lead</td>
<td>Silver</td>
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<tr>
<td>Tin</td>
<td>Titanium (passive), Hastelloy C &amp; C276 (passive)</td>
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<tr>
<td>Inconel 600 (active)</td>
<td>Graphite</td>
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<tr>
<td>Nickel (active)</td>
<td>Zirconium</td>
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<tr>
<td>60% Ni 15% Cr (active)</td>
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<td>80% Ni 20% Cr (active)</td>
<td>Platinum</td>
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<tr>
<td>Hastelloy B (active)</td>
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<tr>
<td>Naval Brass (CA464), Yellow Brass (CA268)</td>
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<tr>
<td>Red Brass (CA230), Admiralty Brass (CA443)</td>
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Ground Connection

Cadweld

Sacrificial Anode
Zinc from Swamp Cooler

Best Practice
Coat with Roofing Tar

Pipe over conductors
adds Moisture and Ions
Water Softener Drain
CaCl and MgCl
Other Options

- [http://www.arrl.org/FandES/field/regulations/insurance/equipment.html](http://www.arrl.org/FandES/field/regulations/insurance/equipment.html)


- Take up a new hobby.
Thanks

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