

Antenna Safety

General Safety – Use Common Sense

- In the attic – don't slip and fall through the ceiling
- Work safely on roofs – the roofer is required to have safety harnesses by OSHA (personal fall arrest systems) if exposed to a fall of over 6 feet. Remember that when you are walking around untethered
- Best to have someone who can help you if you get hurt or stuck
- Even a short fall can cause serious injury or death and the seriousness of the injuries increase the older the person is at the time of the fall



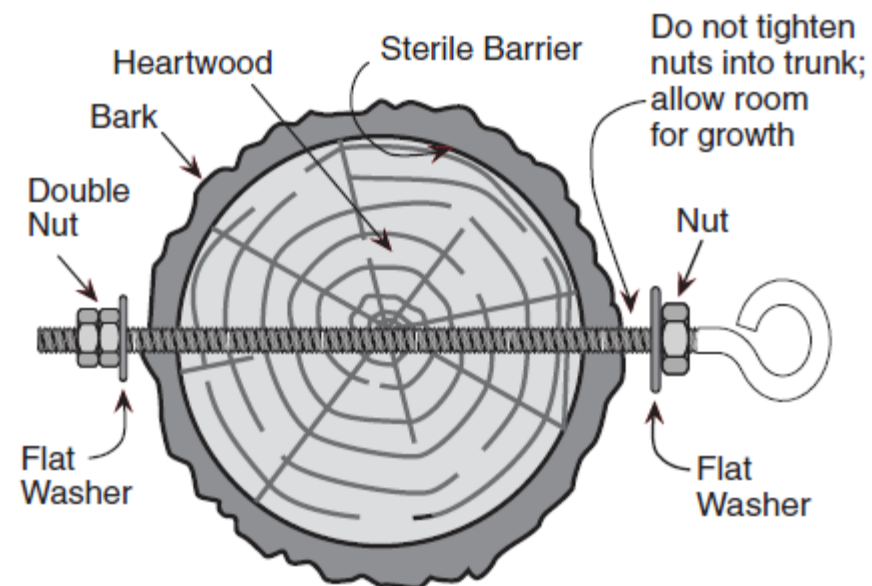
General Antenna Safety – Power line concerns

- Keep all objects as far away from power lines at all times – at least 10 feet away from power lines or electrical service “drops”
- Never assume that the power wire is adequately insulated.
- Don’t rely on fiberglass or wood poles to act as insulators
- Know electrical first aid
- Do not work alone

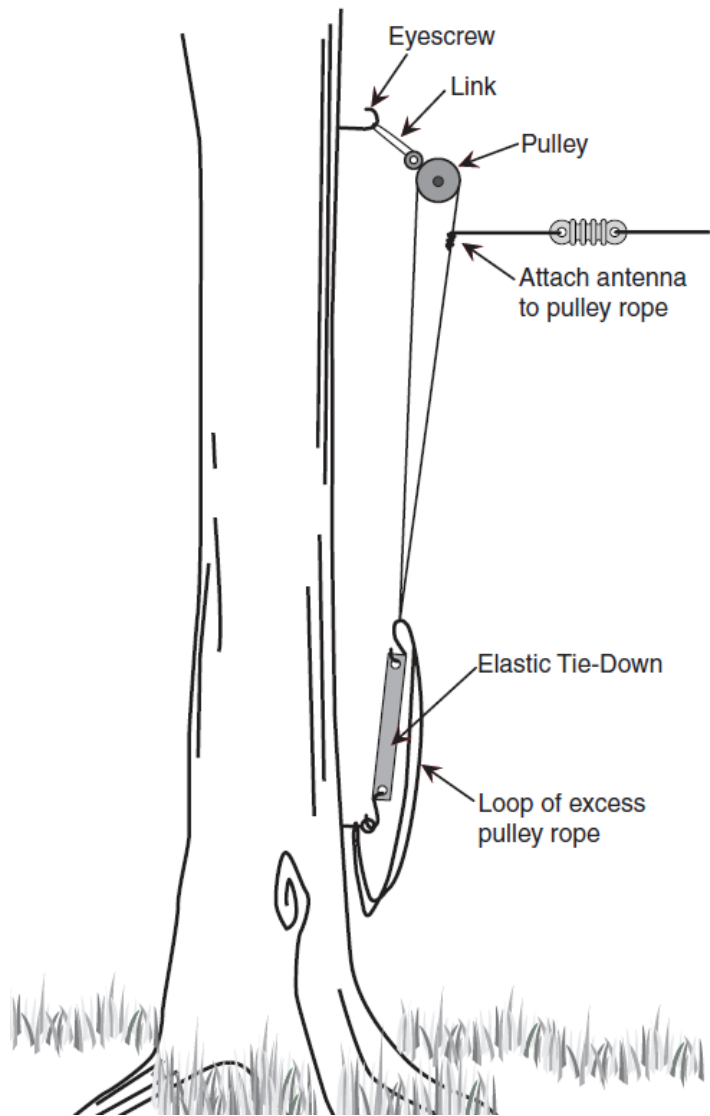


Using Trees

- Consider proper anchors – I Bolts through the tree. Simply wrapping the tree with the halyard could “strangle” the tree
- I use a rope mounted pulley and pull the antenna halyard through the pulley.
- Use a system for maintaining tension on the antenna but permitting swaying of the trees.
- Tree climbing is not trivial. Use sturdy boots with spurs, TWO lanyards (so you can “leap-frog” above and below branches in the way without being tied in), and safety belt.

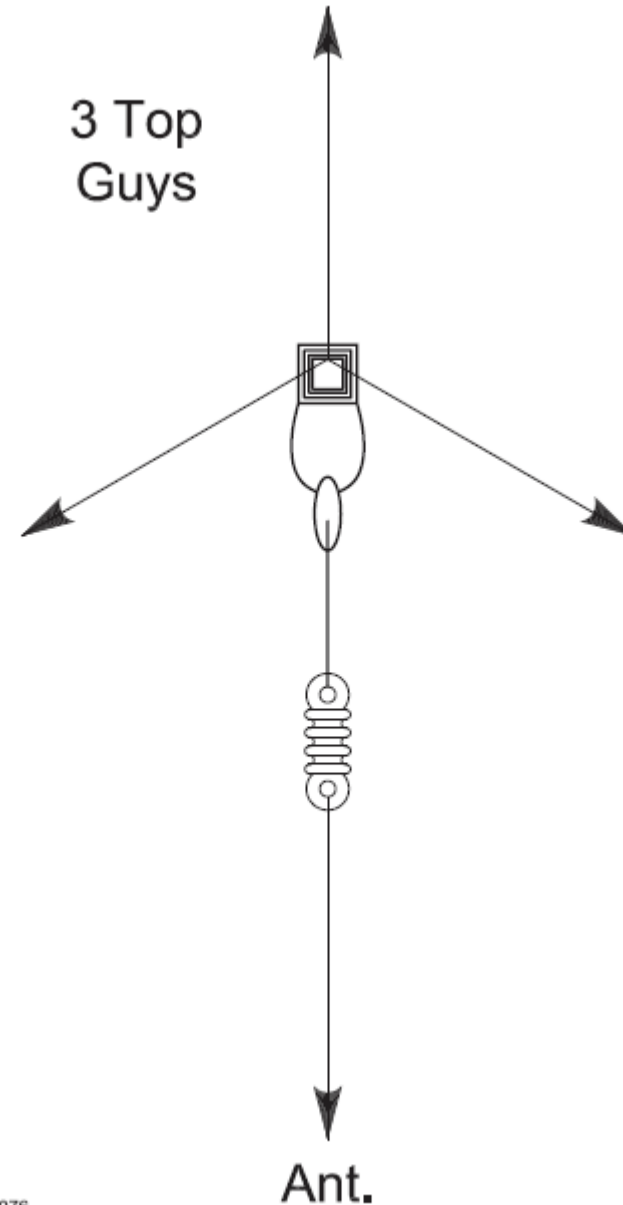


From the ARRL Antenna Book, 23rd Edition



Masts and Poles

- Lightning protection
- Guying:
 - Use at least 3 guys at 120° apart
 - Best if one guy is directly opposite the antenna
 - Use appropriate anchors
 - Use proper tensioning (approximately 10%-15% of the working load is sufficient).
 - Use appropriate material for guy wires. Consider near field antenna effects of metal guy wires.



ANT1076

From the ARRL Antenna Book, 23rd Edition

Tower climbing safety

- Proper harness
- Proper clothing
- Proper tools
- Proper training
- Assistance
- Best Plan – hire someone with all of the above plus all required licenses and insurance



Crank up and tilt over Towers

- Present special safety issues
- Use protection from sudden collapse
- Make sure locked in place when finished

Wind Loading

- Get help if you are not trained to do the calculations and/or do not fully understand the requirements
- Wind load calculation minimum speeds can differ based on elevation of site and type of exposure of the site
- There are maps with ultimate wind speed exposures (e.g., Douglas county, CO has requirements as low as 105 mph and as high as 130 mph).

June 22, 2016, W3LPL's
200' Rotating Tower
collapsed



Tower Failure

One author (Consolidated Engineering, Inc.) found the top 5 causes of tower failure were:

Construction Errors	31%
Ice	29%
Special Wind	19%
Aircraft	11%
Anchor Failure	10%

Tower erecting and ongoing maintenance is not a trivial task. Get help.

General Antenna Safety Take Aways:

- Use common sense
- Be aware of overhead dangers
- Beware of fall risks
- Use proper safety gear
- Don't do things you are not trained to do
- Hire experts

RF Exposure Limitations

- Effective May 3, 2021, there are new rules for RF exposure, with existing stations given until May 3, 2023 to come into compliance.
- Under the old rules, there were automatic exemptions. Now you have to determine if you qualify for an exemption, if not, then whether you comply with the limits.
- If you change your station prior to the 2023 deadline you need to come into compliance.
- The new rule does not change the RF exposure limits.



Why does anyone care about RF exposure

If RF radiation is absorbed by the body in large enough amounts, it can produce heat, leading to burns and tissue damage.

Evaluation and documentation

- Perform the analysis and verify compliance.
- Two sets of limits:
 - Occupational/controlled exposure
 - General population/uncontrolled exposure
- You are measuring whether you are below the MPE (maximum permitted exposure) levels – looking at electric and magnetic field strengths and plane-wave equivalent power densities.
- Document the analysis and file it so it can be produced to the FCC upon request. No need to file with the FCC, just keep the analysis.

Maximum Permissible Exposure (MPE)

Figure 1. FCC Limits for Maximum Permissible Exposure (MPE)

Plane-wave Equivalent Power Density

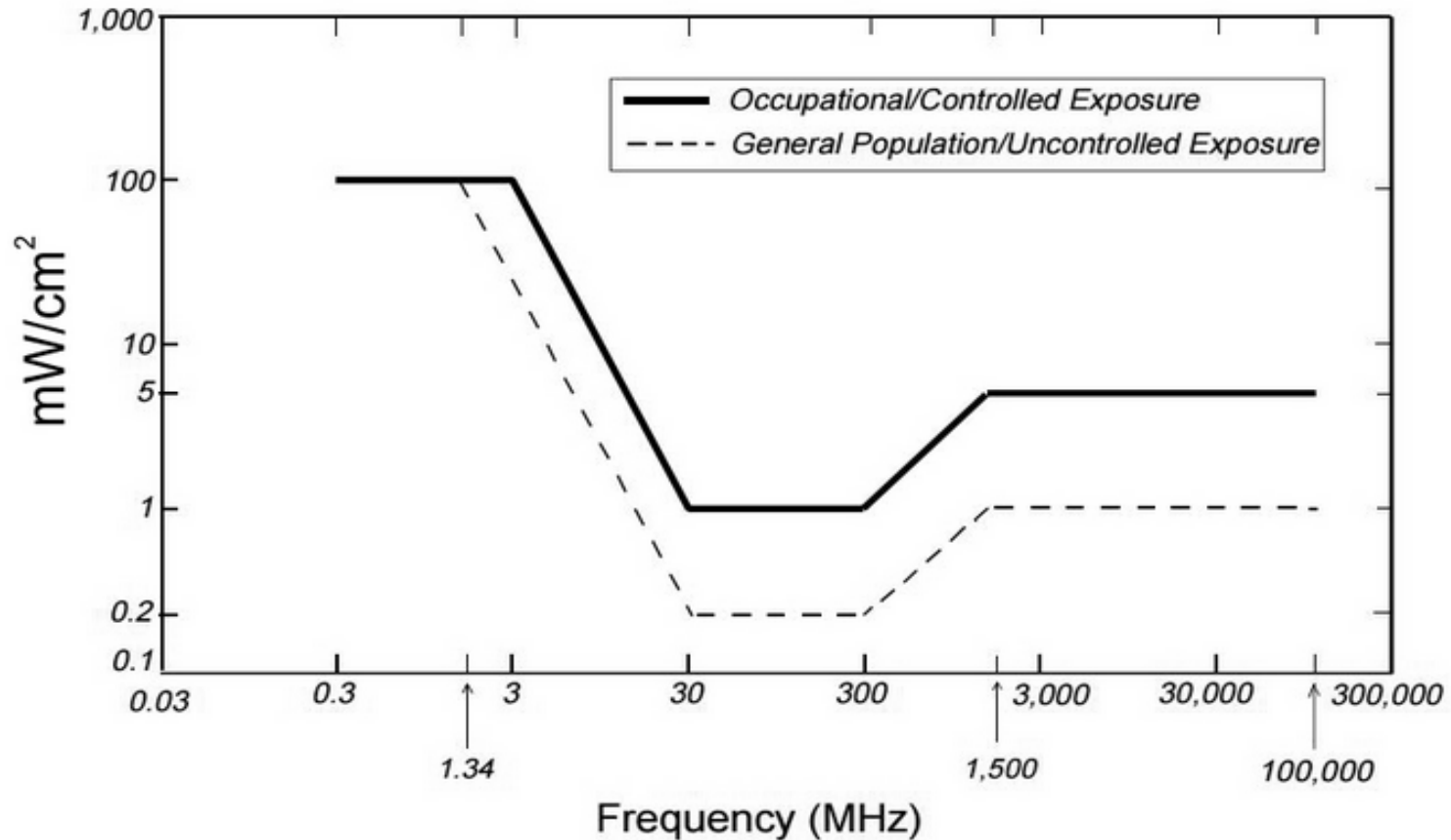


Table A**(From §1.1310) Limits for Maximum Permissible Exposure (MPE)****(A) Limits for Occupational/Controlled Exposure**

<i>Frequency Range (MHz)</i>	<i>Electric Field Strength (V/m)</i>	<i>Magnetic Field Strength (A/m)</i>	<i>Power Density (mW/cm²)</i>	<i>Averaging Time (minutes)</i>
0.3-3.0	614	1.63	(100)*	6
3.0-30	1842/f	4.89/f	(900/f ²)*	6
30-300	61.4	0.163	1.0	6
300-1500	—	—	f/300	6
1500-100,000	—	—	5	6

f = frequency in MHz

* = Plane-wave equivalent power density (see Notes 1 and 2).

(B) Limits for General Population/Uncontrolled Exposure

<i>Frequency Range (MHz)</i>	<i>Electric Field Strength (V/m)</i>	<i>Magnetic Field Strength (A/m)</i>	<i>Power Density (mW/cm²)</i>	<i>Averaging Time (minutes)</i>
0.3-1.34	614	1.63	(100)*	30
1.34-30	824/f	2.19/f	(180/f ²)*	30
30-300	27.5	0.073	0.2	30
300-1500	—	—	f/1500	30
1500-100,000	—	—	1.0	30

f = frequency in MHz

* = Plane-wave equivalent power density (see Notes 1 and 2).

Note 1: This means the equivalent far-field strength that would have the E or H-field component calculated or measured. It does not apply well in the near field of an antenna. The equivalent far-field power density can be found in the near or far field regions from the relationships: $P_d = |E_{total}|^2 / 3770 \text{ mW/cm}^2$ or from $P_d = |H_{total}|^2 \times 37.7 \text{ mW/cm}^2$.

Note 2: $|E_{total}|^2 = |E_x|^2 + |E_y|^2 + |E_z|^2$, and $|H_{total}|^2 = |H_x|^2 + |H_y|^2 + |H_z|^2$

How do I perform the Analysis?

- There are online tools that make it easy
- <https://rf.packetwarriors.com/>
- <http://arrl.org/rf-exposure-calculator>
- https://hintlink.com/power_density.htm
- Suggestion: Start with the highest HF frequency at which you operate unless you operate at higher power or have higher gain antenna at a lower frequency. If you find you are well under the limits it is likely you won't have a problem at other frequencies (unless you are operating high power on 6m or 2m or have very high gain antennas. Don't forget that you're obligated to do analysis on all bands you operate.

What do I do if I exceed the MPE?

- Calculations may be looking at worst case parameters. Make them more realistic to the way you operate.
- Evaluate using modeling software (EZNEC) for a more accurate assessment
- Alter your antenna – the location of my vertical antenna is exposed. For 10 meters I may need to use a dipole that's elevated
- Cut back on your power. There may be situations where you can't fire up that 1.5KW space heater
- Decrease your talk time – listen more
- Put up a fence and warning signs to keep people greater distance away
- Don't operate when people are around

RF Exposure Take Aways

- Even though the FCC now requires an analysis and documentation of that analysis, most stations will pass.
- Don't file with the FCC. Just keep the analysis so you can produce it to the FCC on demand.
- Use an on-line tool to evaluate.
- The exemption is harder to get than it is to just perform the analysis.
- If you the on-line tool shows that you exceed the limits, go back and make sure you have an accurate assessment of the antenna(s) you are using
- If you fail, then take the steps to mitigate the exposure.

National Electrical Code (NEC) antenna requirements

- One version or another of the NEC has been adopted in your jurisdiction
- NEC prohibits attaching an antenna to the electrical service mast
- Avoid crossing conductors of power circuits. If unavoidable a minimum of 2' of clearance is required.



More NEC:

- **NEC Section 810.52** Minimum size of outdoor antenna conductors:

	Less than 45 m (150 ft)	Over 45 m (150 ft)
Hard drawn copper	#14 AWG	#10 AWG
Copper clad steel or other high strength material	#14 AWG	#12 AWG

- **NEC Section 810.53** Lead-in conductors for transmitting shall be at least as great as the antenna size specified above.
- **NEC Section 810.55** - lead-in conductors must go through rigid, non-combustible, nonabsorbent tube or bushing, or through an opening with at least 50 mm (2 in.) of clearance, or through drilled windowpane.
- **NEC Section 810.56** – lead-in conductors should be installed so as to make accidental contact with them difficult

Still More NEC:

NEC Section 810.21 – Grounding conductors for lightning protection must be as big as the antenna lead-in but **NO SMALLER THAN** #10 AWG copper, #17 AWG copper-clad steel, or #8 AWG Aluminum.

NEC Section 810.21 If grounded separately from the building electrical system the grounding system must be bonded to the building ground system using **AT LEAST** #6 AWG bonding jumper

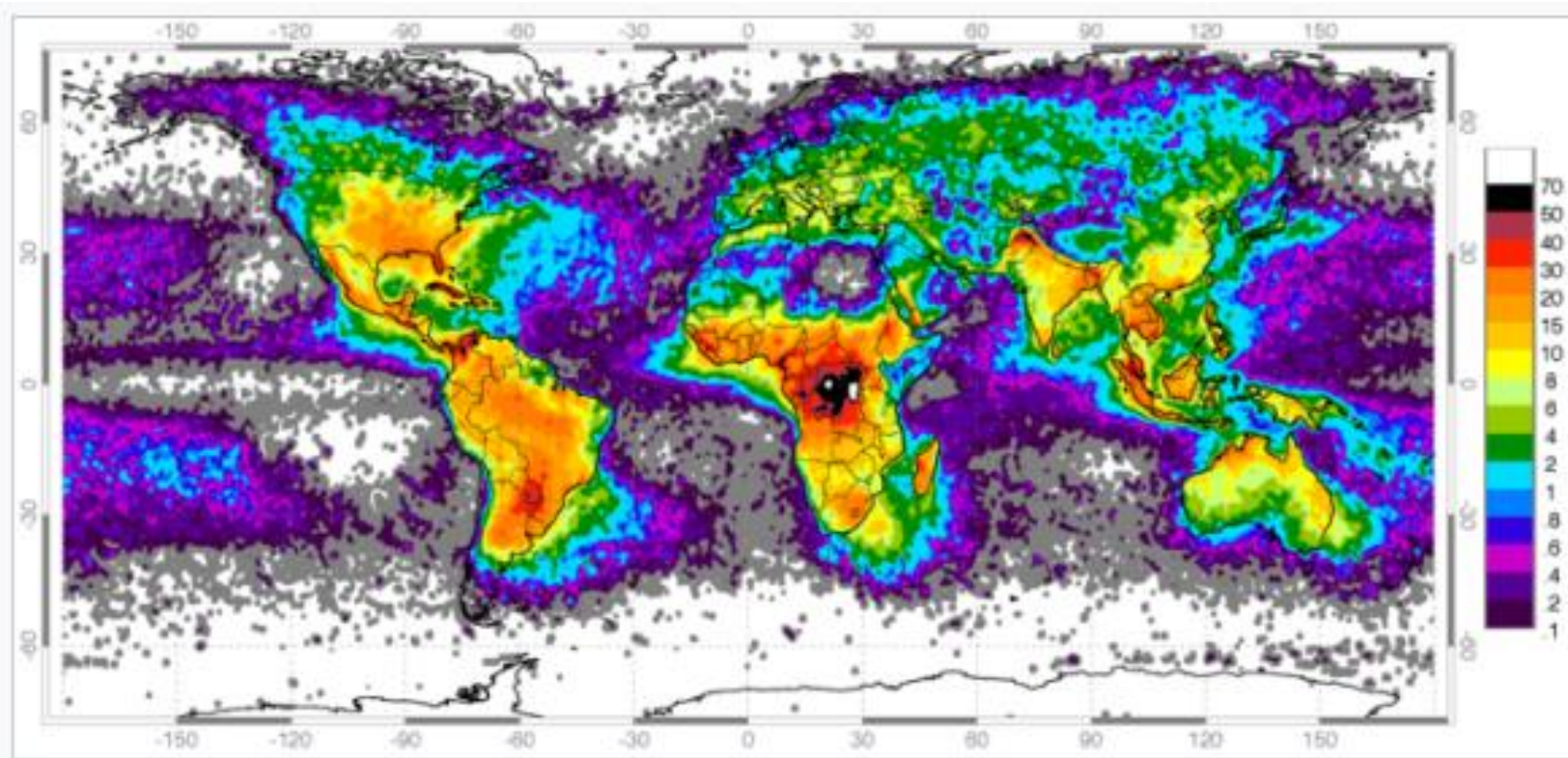
And Still More NEC:

- The NEC has rules that apply to grounding:
 - **NEC Section 810.15** – Outdoor masts and metal structures that support antennas must be grounded
 - **NEC Section 810.20** – Each feedline or lead-in conductor from an antenna must have a listed antenna discharge unit (a/k/a lightning arrestor or lightning protector) – which itself must be grounded. If you are using a Single Point Grounding System, it should be mounted on that.

Summary – Antenna Safety

1. Use common sense. You do not want to be a danger to yourself or to others, including, but not limited to your family.
2. Avoid power lines.
3. Perform the required RF Emissions calculations to confirm that you are in compliance.
4. Get an expert to help with engineering, including calculation of wind loads and compliance with local requirements.
5. Pull permits if required.
6. The NEC has requirements failure to comply could cause problems, both in terms of risk to you and others, and with respect to insurance coverages should you suffer an insurable event.

Lightning Protection



Data from space-based sensors reveal the uneven distribution of worldwide lightning strikes. Units: flashes/km²/yr. Data obtained from April 1995 to February 2003 from NASA's Optical Transient Detector and from January 1998 to February 2003 from NASA's Lightning Imaging Sensor.

How often does lightning occur?

According to Wikipedia:

On Earth, the lightning frequency is approximately $44 (\pm 5)$ times per second, or nearly 1.4 billion flashes per year and the average duration is 0.2 seconds made up from a number of much shorter flashes (strokes) of around 60 to 70 microseconds.

In general, cloud to ground lightning flashes account for only 25% of all total lightning flashes worldwide.



Electrical properties of lightning

- Most strikes have 3-4 impulses
- Peak current for the first impulse averages around 18 kA (98% fall between 3 kA and 140 kA). Second and following pulses are usually about half the size of the initial pulse.
- Interval between pulses is approximately 50 ms.
- The majority of the energy is “pulsed dc”, but the fast rise time (between 0.25 μ s and 12 μ s), generates RF energy.
- When the lightning actually hits the ground, the rise time can shorten to 10 ns.
- Lightning can have RF energy from 10 MHz to 100MHz

Lightning detection systems

- Websites/programs:
 - LightningMaps.org
 - Blitzortung.org
 - iWeather.net.com
- iPhone and google apps:
 - My Lightning Tracker & Alerts
 - Spark
- Build your own with an Arduino or Raspberry Pi or using Node-Red
- Others?

Goals of lightning protection:

- To direct the path of the current generated by one or more lightning strikes
- Prevent large voltage differentials between different points where the resulting current path could damage any part of your station or the structure where it is located
- Create a “zone of protection” and put everything you need to save inside that zone

Use a block diagram to
Analyze what needs
to be protected

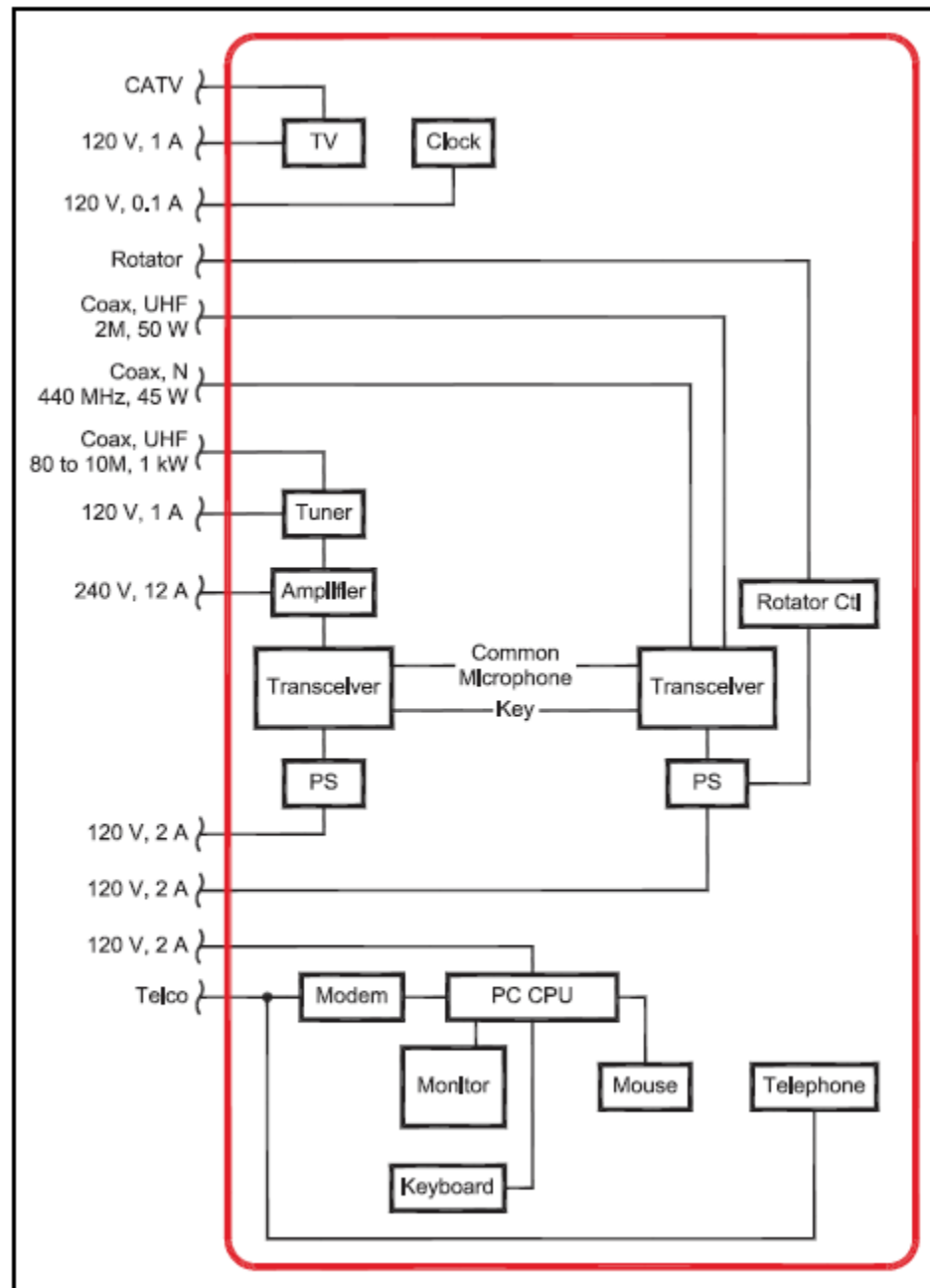


Figure 6—Lines that penetrate the circle are the radio station I/O circuits that must be protected.

From: Lightning Protection for the Amateur Station,
by Ron Block, KB1UYT, June 2002 QST

AC Power Ground

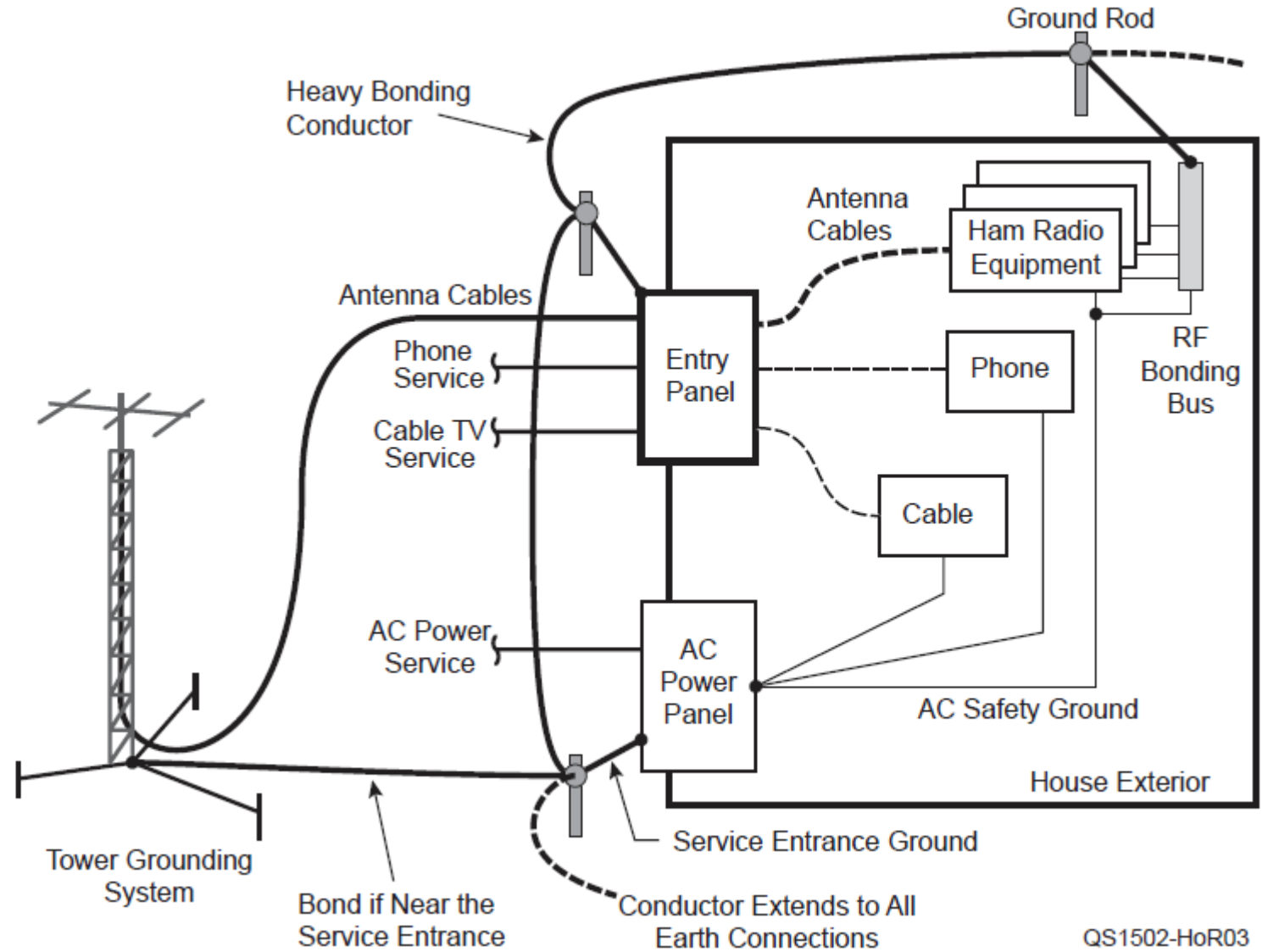
- This is the “green wire” or the third prong on your electric plugs. Designed to provide a safe path for power that shorts to the chassis of your gear.
- Do not disable or cut off the third prong. Proper use of the adapter involves connecting the “tab” to the ground terminal.
- This is relevant to lightning protection for the purposes of “bonding.”



Create perimeter ground

- Use ground rods, preferably 8' long driven completely into the ground vertically
- Use more than one ground rod, preferable every 16 feet for 8 foot ground rods.
- Separate rods by a distance twice as long as the rods (i.e., for 8' rod, separate by 16')
- In poor soils (i.e., sandy) wire acts as if suspended in air due to inductance so use copper strap. 1-1/2" strap is usually effective.
- Make a solid mechanical connection. Usually a clamp is used, but exothermic weld is best. Don't underestimate the need for a solid mechanical connection. The forces associated with lightning are strong. Do not use solder for grounding or bonding connections.
- Best if the perimeter surrounds the structure completely. If not do as much as you can. With direct strike rise times of 10 ns, there can be quite a voltage differential between the grounding system and any portion of the building outside the line of protection.
- Always bond to the building ground system regardless of how much of the perimeter is covered.

Figure 26.50 — A lightning protection system attempts to dissipate charge outside the home or station. All earth connections are bonded together to provide a low-impedance path for lightning, and to minimize voltage differences and current flow between equipment and circuits.



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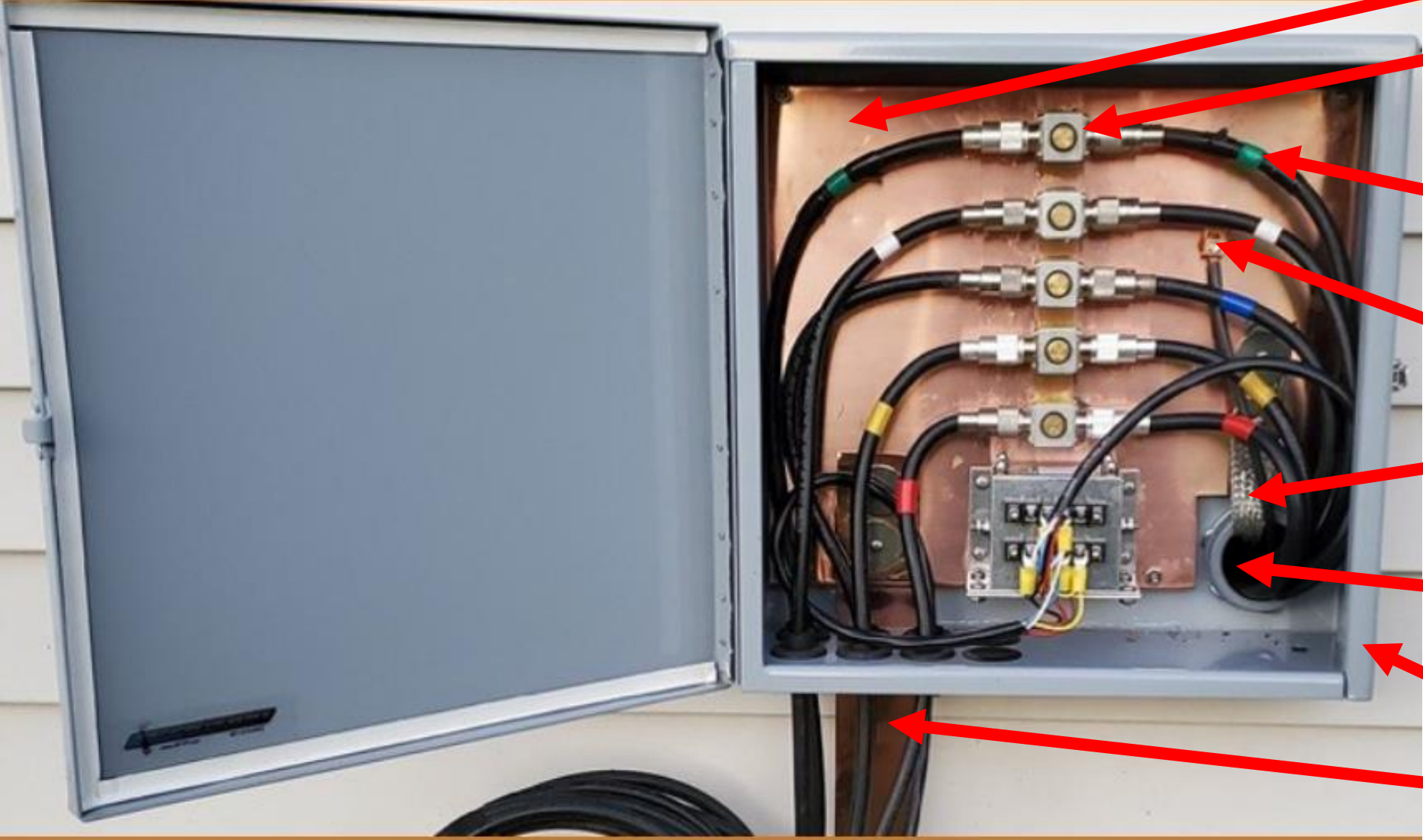
From ARRL Antenna Book, 23rd Edition (2017-2018)

Note: It would be better to bond the RF bus directly to the ground rod and not the AC Safety Ground

Use a single point grounding system

- These are sold by businesses like KF7P in Utah. Or make your own.
- Connect the Single Point Grounding System to the perimeter ground system with copper strap (remember the skin effect so strap is more effective and has less inductive reactance)
- Use conduit to enter the shack for both grounds and antennas
- Mount the lightning arrestors directly on the Single Point Grounding System
- Use an internal star or bus grounding system connected to the SPGS using wire braid as the RF ground.

All these components including the box itself are available from KF7P in Utah.



Solid Copper back plate

AlphDelta Lightning arrestor

Color coded Coax Markings

Station Ground

Station RF Ground Braid

Conduit to shack

Waterproof exterior entry panel

Copper Strap



Note: AlphaDelta arrestors permit replacing the gas discharge tubes (i.e., the entire brass threaded cap on top), some from other manufacturers may require replacing the whole unit.

Spark-over voltage should exceed normal operating conditions. Once that level is exceeded, the gas filled tube will permit a hidden conductor to spark and short the center connector to the ground. This protects against surges but will likely be destroyed by a direct hit. By shorting center to ground the differential V is limited and won't be balanced by massive current through your equipment.



Grounding bars can be purchased (such as this one from KF7P) or made. I've seen them made from 1/2" copper tube and hose clamps.

3/4" wide braid with ring terminals with either #10 and/or 1/4" screw sizes.



Flat copper is used due to low inductance. Typically .025" thick and can be purchased in widths from 1" to 3" in practically any length.

Should you just disconnect?

If you go this route, remember you could have kV on the end of the antenna, so disconnecting outside the house would be wiser than doing so inside the house. Also, even a disconnected coax should be grounded.

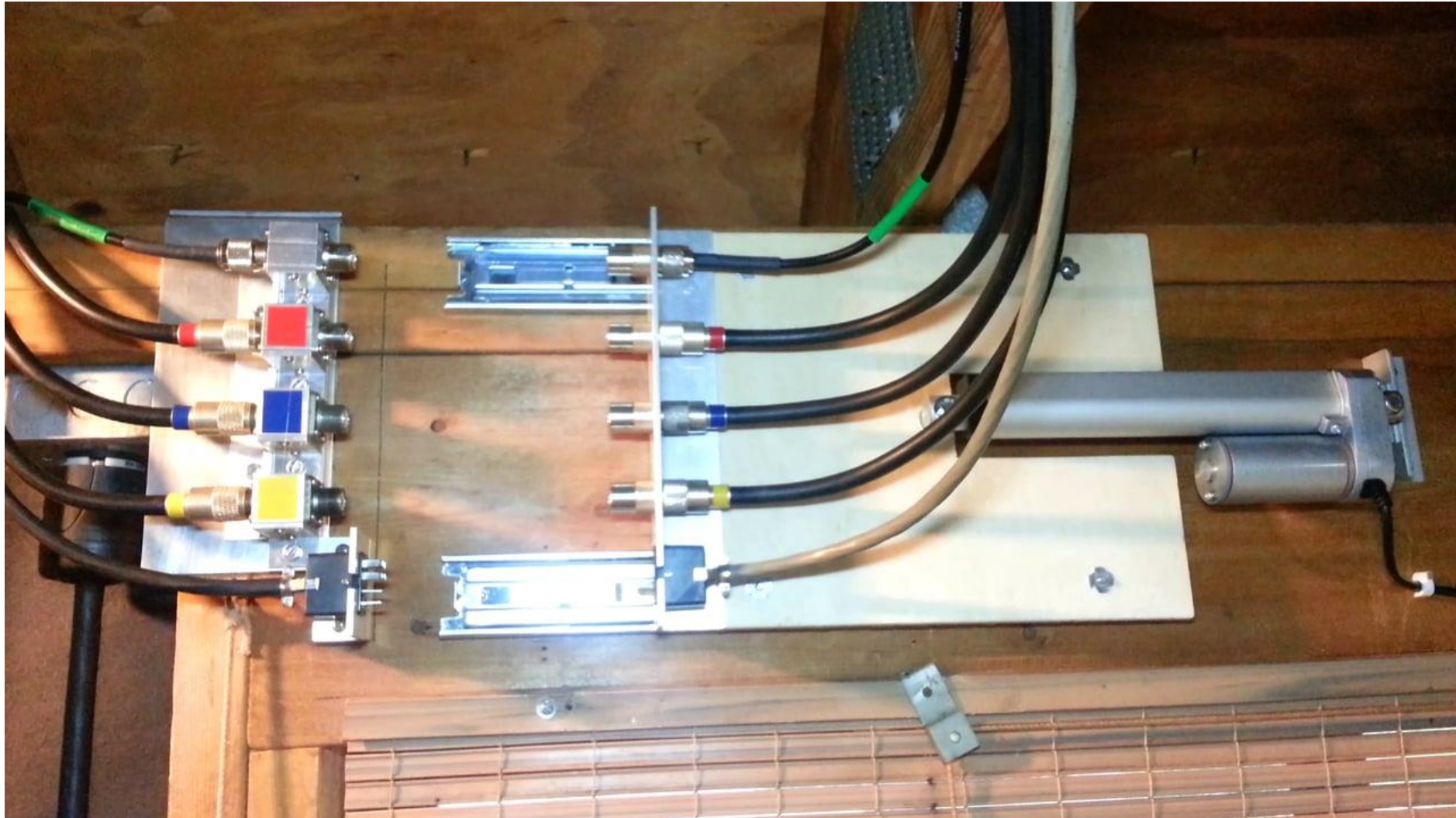


Push-on PL 259 connectors –
make disconnecting faster.



High quality coax switches will short
the center conductor to ground. Very
helpful for discharging static build-up.
Do not consider this a primary source
of lightning protection.

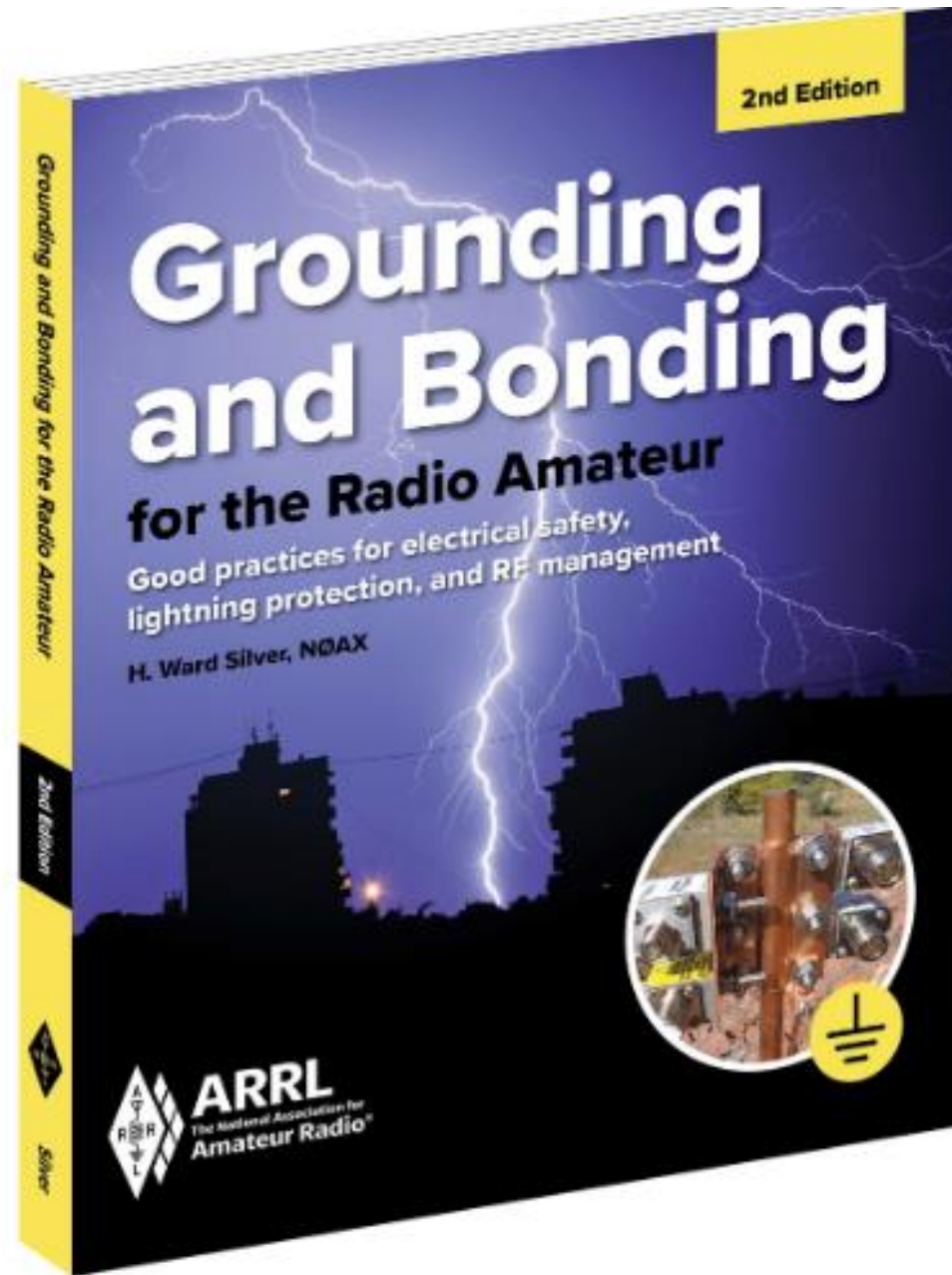
Remote disconnect systems



The perimeter ground MUST be bonded to the building's grounding system and the SPGS

- This is required by the NEC
- This keeps the “potential” of everything attached to the perimeter ground the same level as the other items in the structure. Remember voltage differentials lead to currents over any available conductor and lightning causes differentials in the antenna and in the grounding system.
- Worth confirming that the POTS and CATV wiring is bonded as required as well. Frequently these were installed by those with no experience and, as a result are frequently done incorrectly. At my house it was a separate ground rod for POTS and CATV, not bonded to the structure's electrical ground.

Grounding and Bonding for the Radio Amateur, 2nd Edition, by Ward Silver



Summary – Lightning Protection

- Lightning is an extremely high voltage high current event that
- Create a perimeter ground system with ground rods and interconnect with appropriate wire or strap, depending on the conditions.
- Ensure a strong mechanical connection with each component of the ground system – either bolted or exothermic weld, never solder.
- Use a single point ground system
- Perimeter ground and SPGS need to be bonded to the building ground system and make sure that other paths to items inside the protected perimeter are bonded to the building ground system too.