

BONDING AND GROUNDING FOR AMATEUR RADIO

John Wagner, N8CD



Some content within is the work
of others, attributed in-line

WHO IS THIS GUY ANYWAY?

- John Wagner, N8CD
- Been a ham since 1978
- Have made lots of mistakes in this area
- Have read about and tried many things
- Been zapped by some of those things

- Came close to burning my parents house down with improper grounding at age 14



DISCLAIMER

- What I'm about to show you will improve your chances against lightning and surges
- If you do some of these things and still get electrocuted, I'm sorry
- I'm not a lawyer, so I probably shouldn't even make these disclaimers



QUESTIONS?

- Ask as we go
 - (Within reason)

PURPOSE OF THIS PRESENTATION

- Types and Reasons for Grounding and Bonding
 - Focus on Lightning and Static protection
- Go over goals and what you're up against
- This is to show you some practical, operational ways to ground and bond
- Talk about some common mistakes you can avoid

WE'RE NOT GOING DEEP INTO THE PHYSICS

- Beef O'Brady's closes at 10PM

$$\nabla_{\dot{x}} \cdot \frac{\partial \mathcal{L}}{\partial \mathbf{p}} + \nabla_{\dot{y}} \wedge \frac{\partial \mathcal{L}}{\partial \mathbf{q}} = 0$$

- I'm not that smart

$$\oint_{\text{全てのスペース}} (E + H \wedge T) \int_{-\infty}^{+\infty} \frac{\partial^2 \mathcal{A}}{\partial \phi \partial z} d\Omega d\tau = \frac{\Gamma(N) \int(\Omega, \tau)}{(2\pi)^N \mathcal{K}}$$

$$dF = \frac{\langle \Phi | \dot{z} | \Psi \rangle}{(2\pi)^N c^2} \left[\gamma d\Sigma + \mathbf{b} \frac{\partial \xi}{\partial z} \wedge d\dot{x} \right]$$

Picture by [F=q\(E+v^B\)](#)



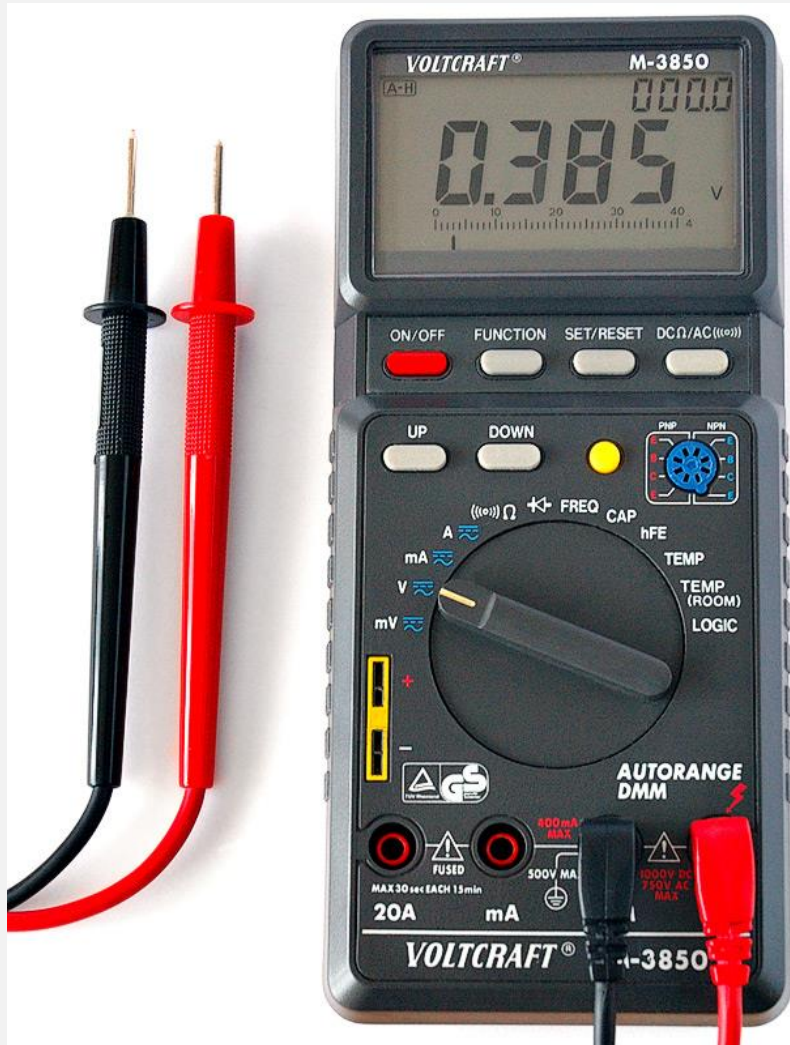
<https://www.flickr.com/photos/mlrs193/>

BEFORE WE DIVE IN...

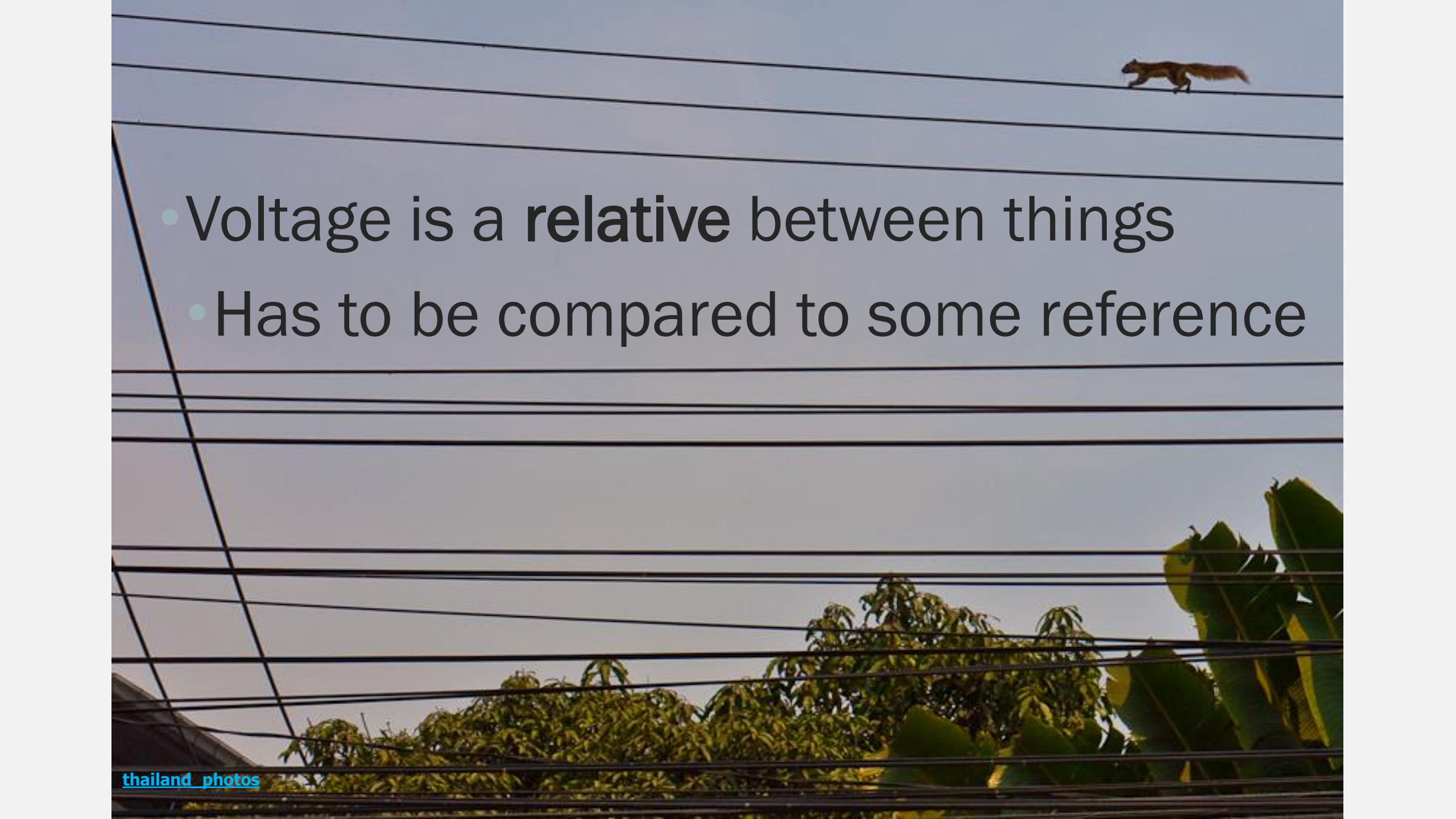
Back
To
School



IMPORTANT BACKGROUND



- Voltage is a **relative** between things
- If something is at 1,000,000 volts compared to something else at 1,000,000 volts, Δ voltage = zero
- For current to flow, need Δ voltage
- High current through even small resistance makes high voltage

- 
- Voltage is a **relative** between things
 - Has to be compared to some reference

REMEMBER OHM'S LAW?

- $E=IR$ (current \times resistance = voltage)

resistance in ground system Ω	amps of lightning	volts across resistance
1	30,000	30,000
0.5	30,000	15,000
0.25	30,000	7,500
0.125	30,000	3,750
0.06125	30,000	1,837

SCHOOL'S OUT – ON TO THE SHOW



Photo by [Linda LaBonte Britt](#)

BONDING



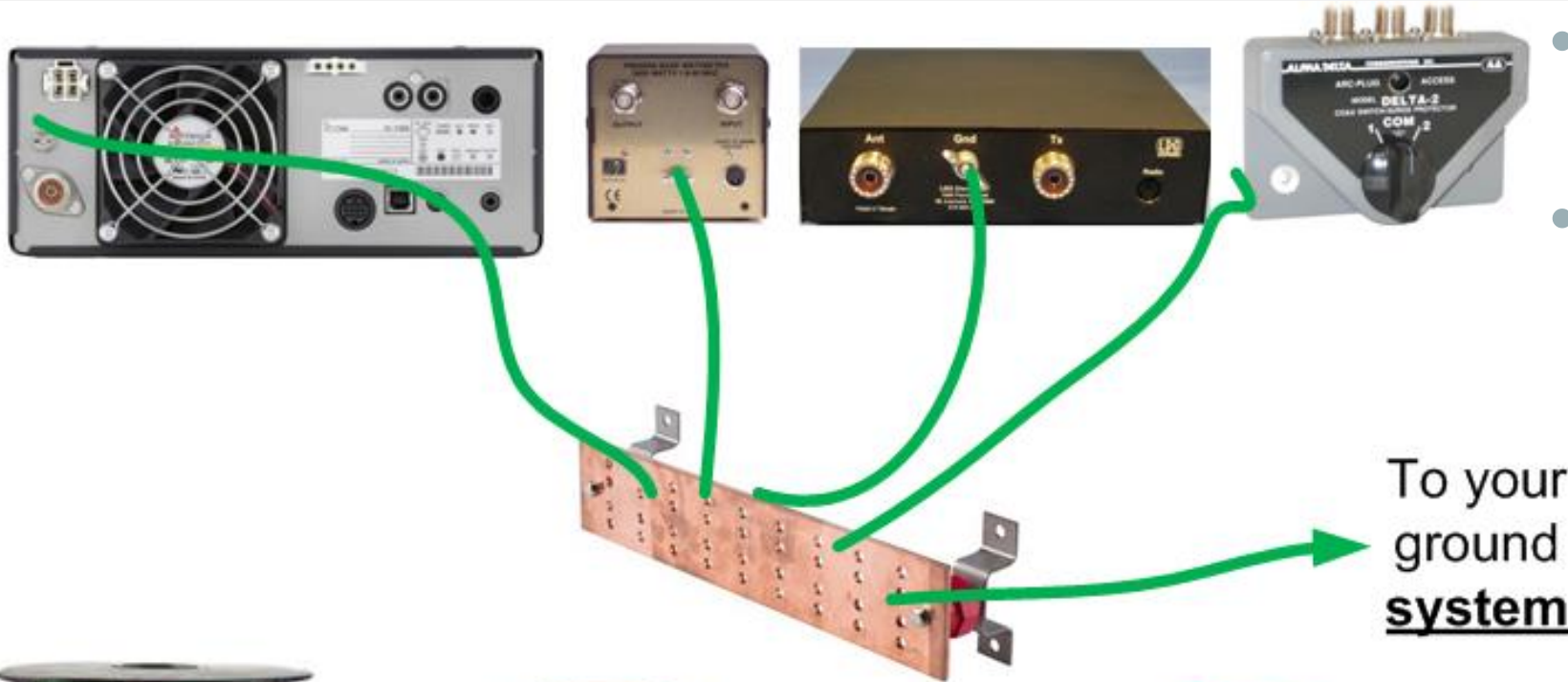
<https://www.pexels.com/@pixabay>

No, not that kind

No, not the other kind either



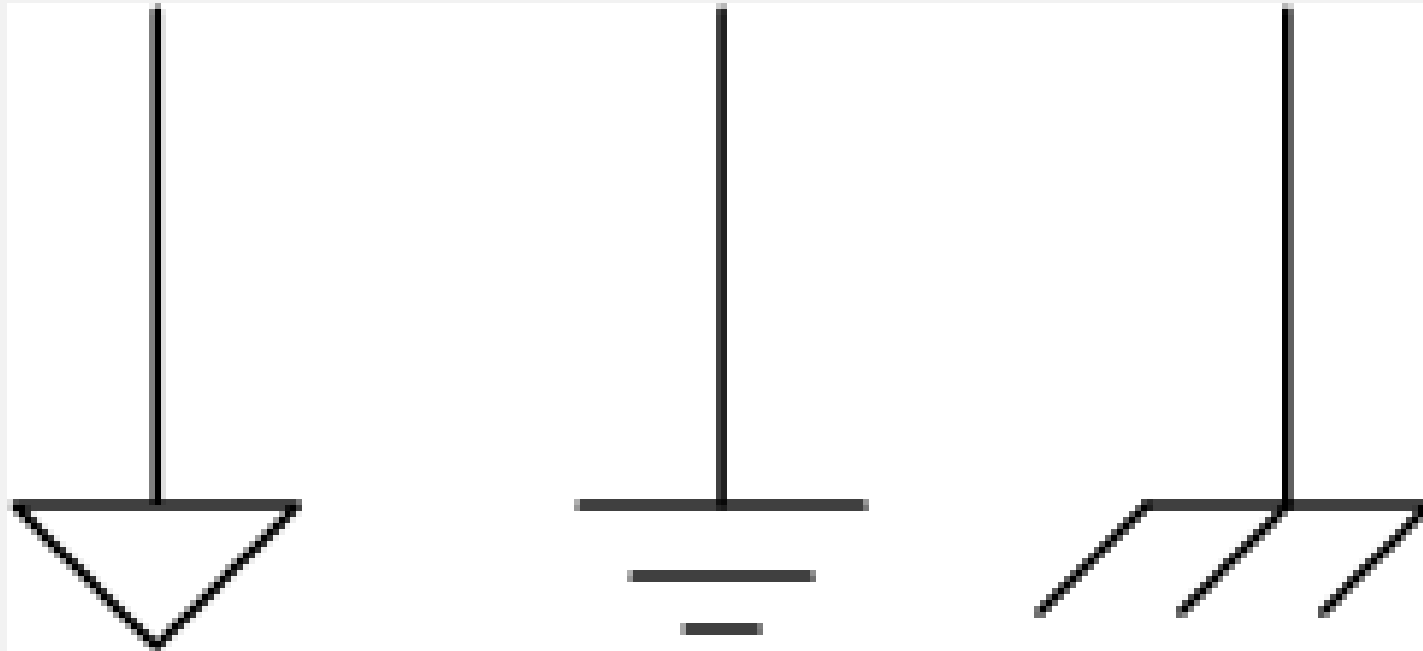
BONDING



- Connects everything together electrically
- Needs to be a low *impedance* path
- Not just low resistance, RF & Lightning aren't just DC
- Bonding helps with
 - Lightning protection
 - RF
 - Safety

GROUNDING

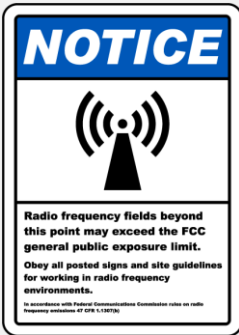
- Lots of definitions



- We're going to use what the British call "Earthing"

3 TYPES OF GROUNDING

Generally compatible



- **Safety**
 - Keep stray house 120/240VAC power from killing you
- **RF**
 - May improve your signal
 - Make things quieter
 - Keep RF out of your shack
- **Lightning/Static protection**
 - Prevent equipment damage
 - Safety from lightning electrocution
 - Give lightning a better place to go



SAFETY GROUNDING

- In many cases this is taken care of for you
 - Grounded electrical panels
 - Grounded AC outlets
- Add your own ground if:
 - Metal chassis with 2 wire AC plugs
 - Older or ungrounded outlets
- Inspect for corrosion and loose clamps
- GFCI outlets can augment safety



[Photo by:Ali K](#)

SAFETY GROUNDING

- Wire should be equal or heavier than the “hot” wire
 - Goal is to trip breaker/fuse if short to chassis
- Don't rely on the white neutral wire alone for safety ground



- Woven braid is usually ok for this
 - As long as it's indoors or temporary, and in good shape
 - I still don't like woven braid
- Add your own ground if your house doesn't have it



RF GROUNDING

- Beneficial for unbalanced antennas especially
 - Verticals, long wires
- Can help reduce RF "bites" in the shack
- Can reduce noise and RF on audio lines
- RF Grounds can be part of antenna counterpoises



RF GROUNDING

- Connecting chassis and shields to earth can reduce noise levels
- Ideally should be bonded to the rest of your ground system

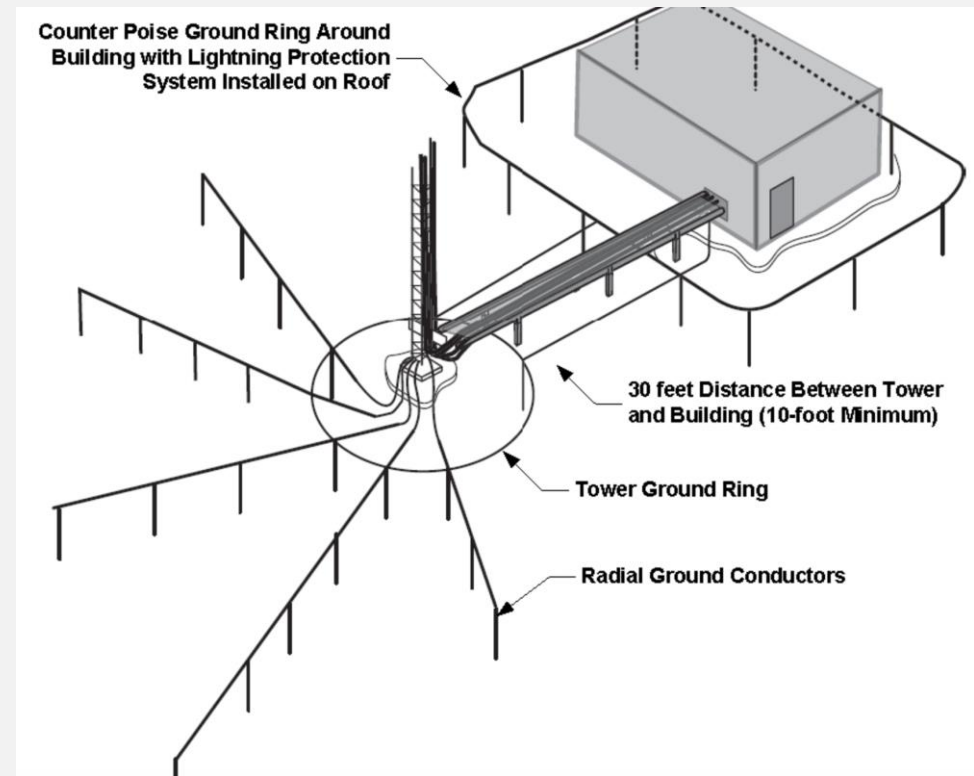


photo by N8JDM

- But...something is better than nothing

LIGHTNING GROUNDING

- One of the goals is a little like protecting your house from rain
- Direct lightning to a safer place
- Shortest, straightest, path with the best flow possible
- Keep it out of your radios



LIGHTNING: WHAT YOU'RE UP AGAINST

- Average lightning bolt:

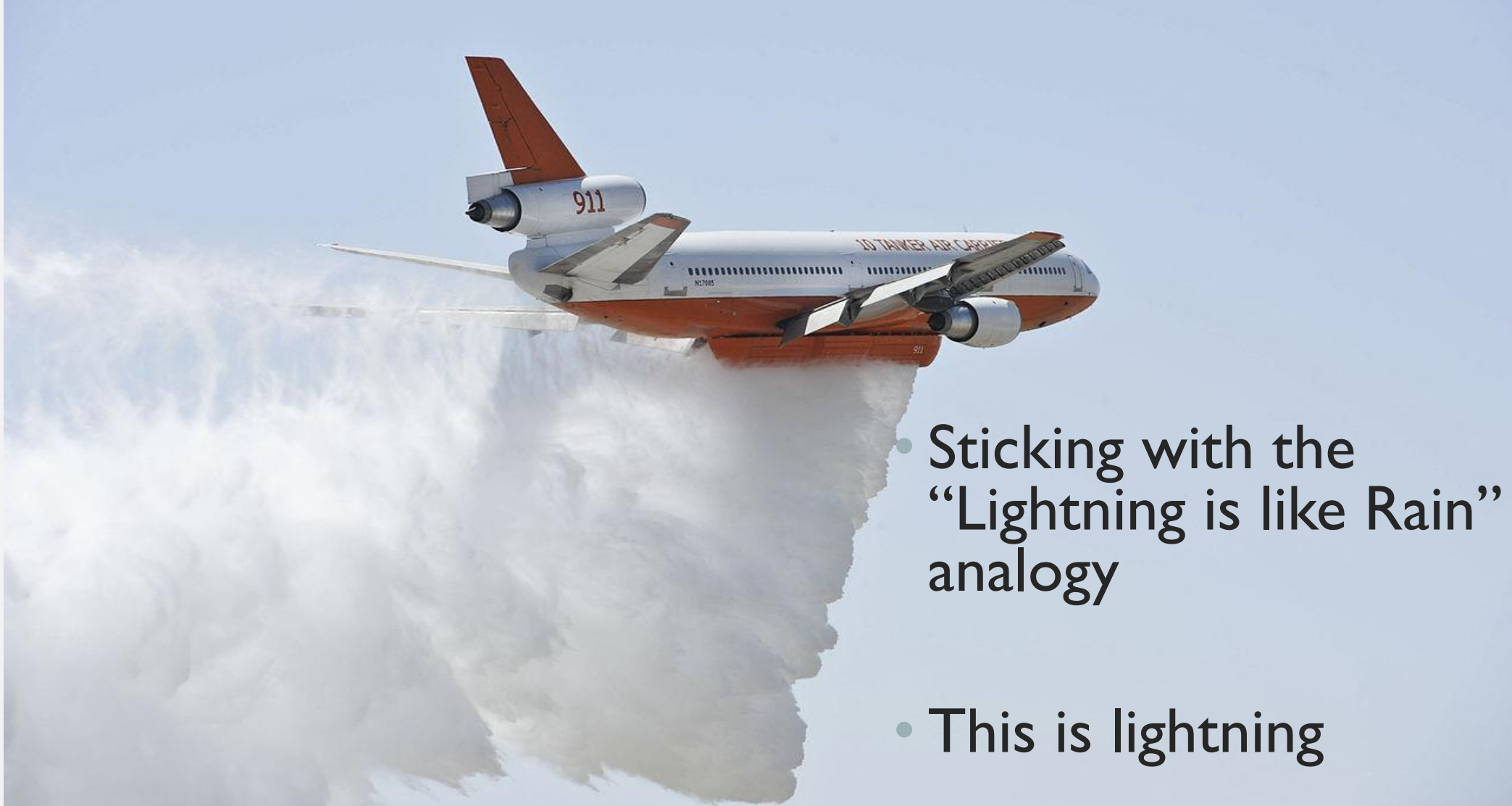
- 100 million volts



- 30,000 amps

- Initial and return strokes
 - Rise time of first stroke around $10\mu\text{s}$
 - Components from D.C. to VHF
 - Strongest from 0.5 MHz to 20 MHz

LIGHTNING & RAIN ANALOGY



- Sticking with the “Lightning is like Rain” analogy
- This is lightning

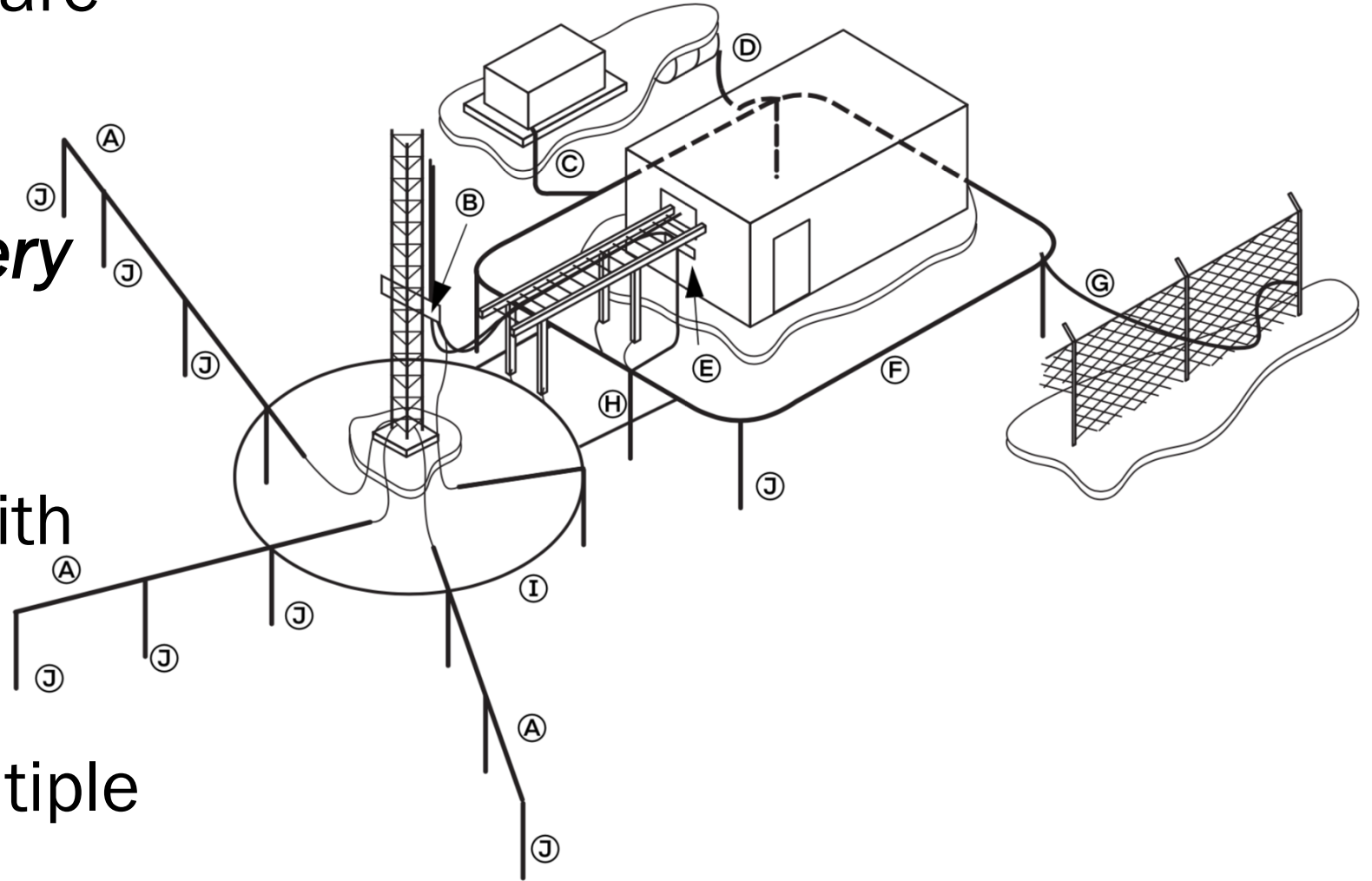
LIGHTNING ISN'T JUST D.C.



- Lightning is super-fast pulse(s)
- Behaves more like RF on wires
- Impedance matters,
 - not just resistance
- Skin effect (current travels on surface of wire)
- Sharp bends and loops in wire have low D.C. resistance but high impedance
- Wire can be resonant at lightning frequencies

SO WHAT DOES A PRO DO?

- The building and tower are purpose built
- Surge protection on **every wire** in and out
- **Everything** is bonded with heavy strap/wire
- Ground screen and multiple well-connected rods



BUT WE'RE AMATEURS

- **Do a Risk Assessment**
 - What's your exposure?
 - A dipole at 20' in a valley or an 80' tower on a hill?
 - What can you afford and want to fix?
 - What can you mitigate with other methods? (disconnecting)
 - What risk will you accept?
 - Low profile stations don't get direct strikes often
 - But nearby strikes can still damage things
- If you decide to do something
 - You can do it in steps

IDEALLY

- Inside: Bond all your equipment together
 - **Shortest, heaviest, straightest, lowest impedance** material you can
 - strap, heavy wire
- Outside: Common entrance panel, outside or at the edge of the building
 - ALL feedlines have grounded shields and quality lightning arrestors
 - Connected to a ground **system**, not just a rod
 - All other wires go through this panel too
 - Phone, power, data

YOUR GOALS

- Bond all your equipment together
 - Short, heavy, straight strap or heavy wire
- Have a single ground point
 - Where everything ties together



- Quality lightning arrestors, ideally outside of your shack
- Surge protection on **all** wires going in and out of your shack

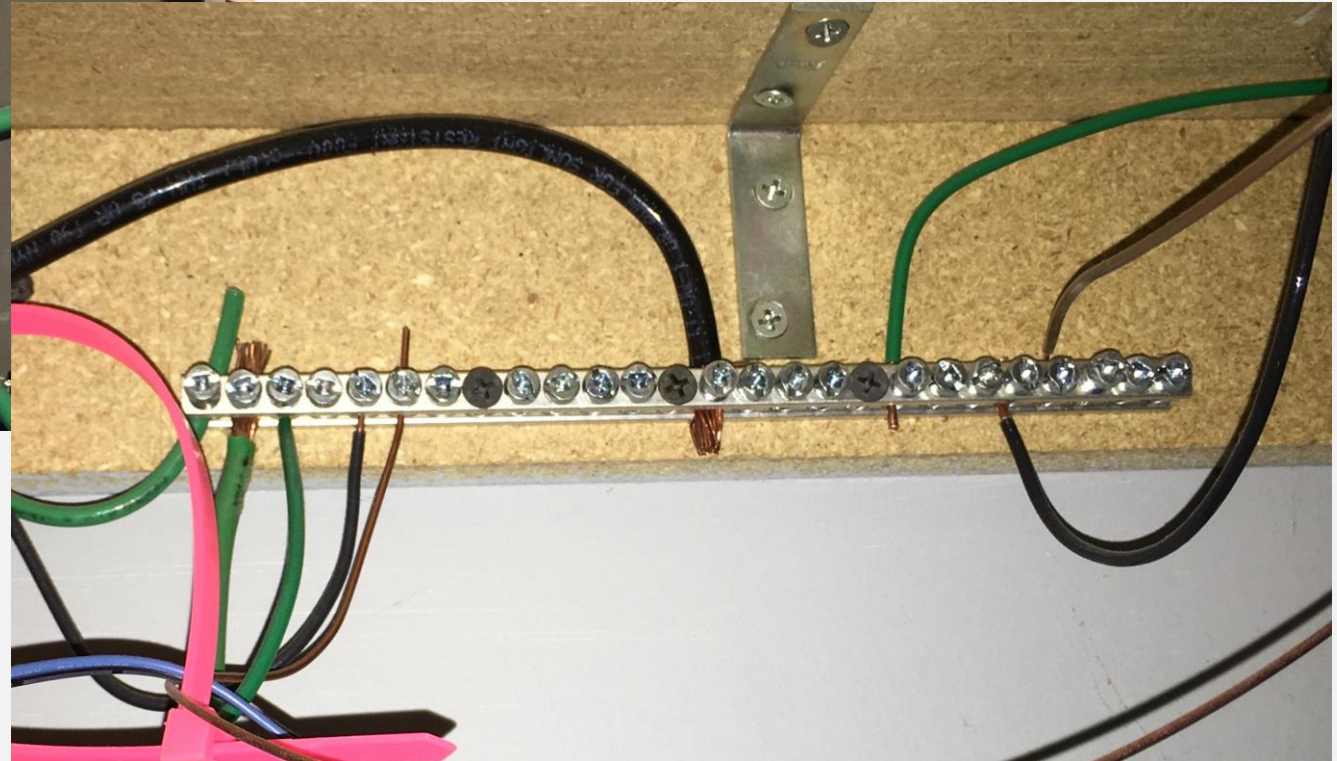
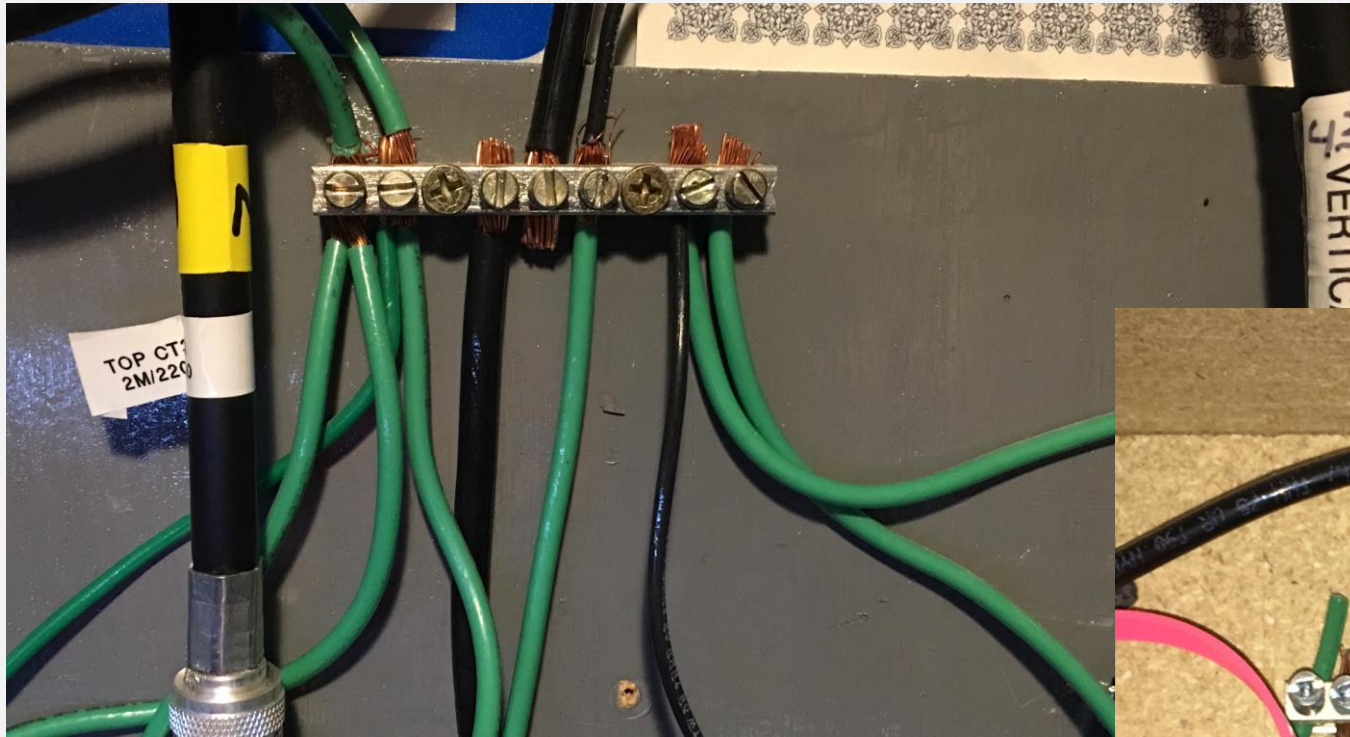
WHAT CAN A HAM DO?

INSIDE

- Connect your inside equipment together to a single ground point with heavy wire or strap
- Don't run unnecessary wires into your shack
 - Phone, Ethernet, CATV
 - Fewer wires = less to protect

WHAT CAN A HAM DO?

INSIDE



WHAT CAN A HAM DO?



INSIDE

- consider a whole house surge suppressor
- If building a shack
 - Consider a shack breaker panel

WHAT CAN A HAM DO?

OUTSIDE

- Connect your towers, masts, outside feedlines through a single ground system with heavy wire or strap
- Lightning Arrestors
 - Outside or barely inside
 - Weatherproof cabinet if outside



WHAT CAN A HAM DO?



OUTSIDE

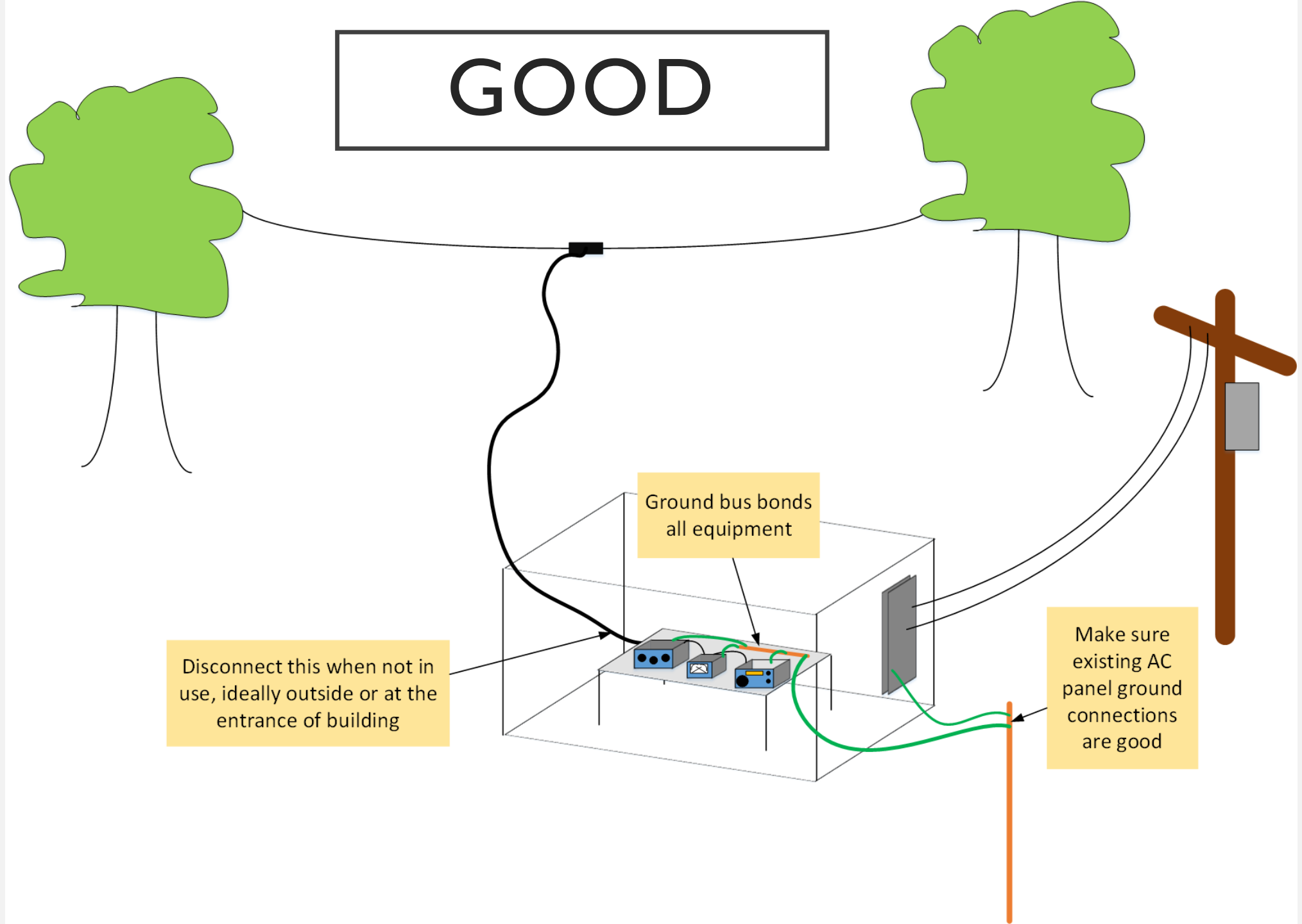
GOOD LIGHTNING GROUND ALSO

- Helps with other surges
 - Snow, Rain, Wind static
 - Nearby lightning strikes

WOW THAT LOOKS EXPENSIVE

- Be creative
 - Hammer out old copper tubing into a ground bus
 - Copper and aluminum flashing (watch dissimilar metals)
 - Scrap wire for grounds (solid or stranded will work)
 - Strip out old heavy Romex for equipment bonding inside
 - Leftover runs from commercial jobs
 - Dumpster dive (with permission)

GOOD

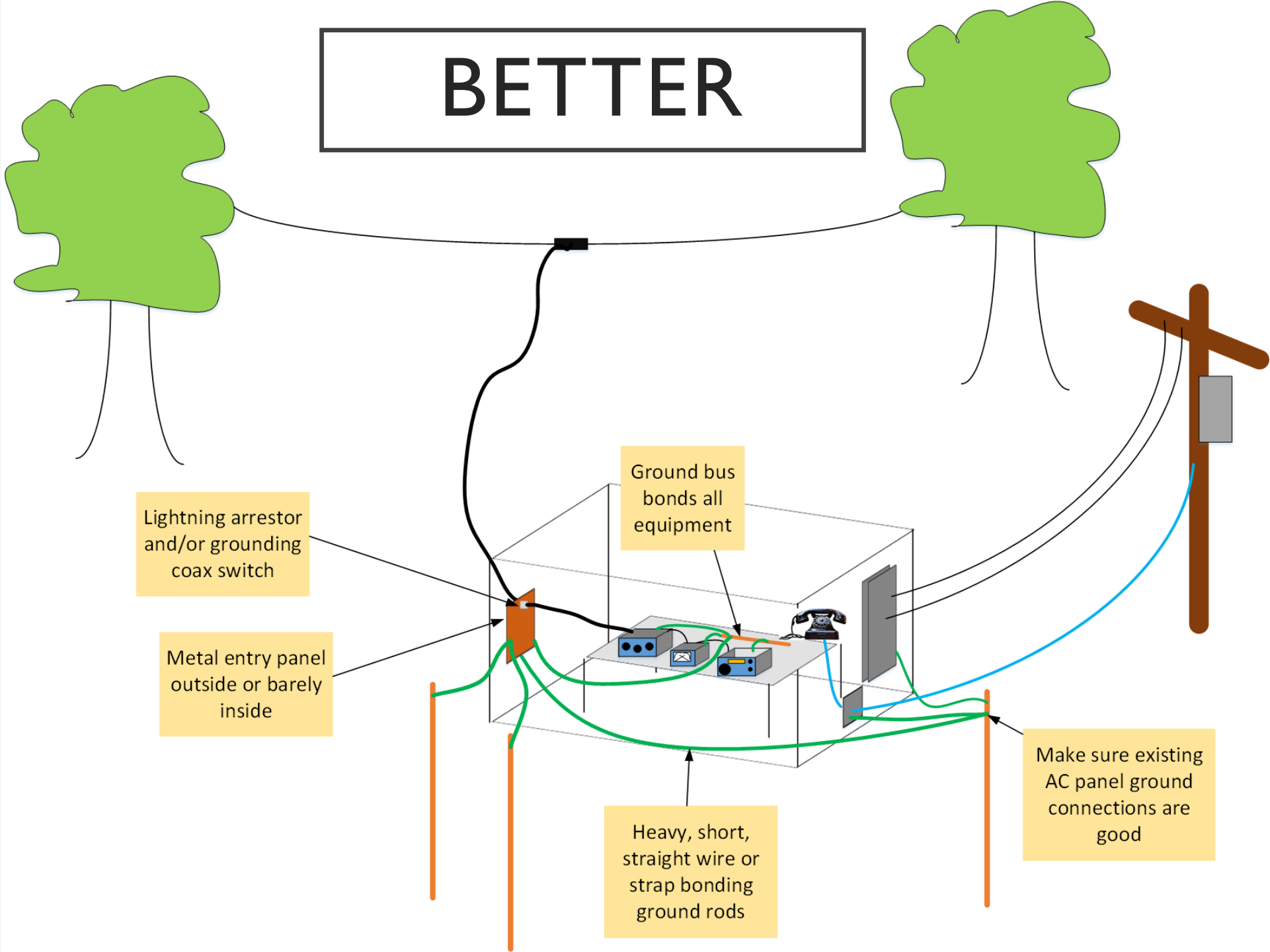


Disconnect this when not in use, ideally outside or at the entrance of building

Ground bus bonds all equipment

Make sure existing AC panel ground connections are good

BETTER



Lightning arrester and/or grounding coax switch

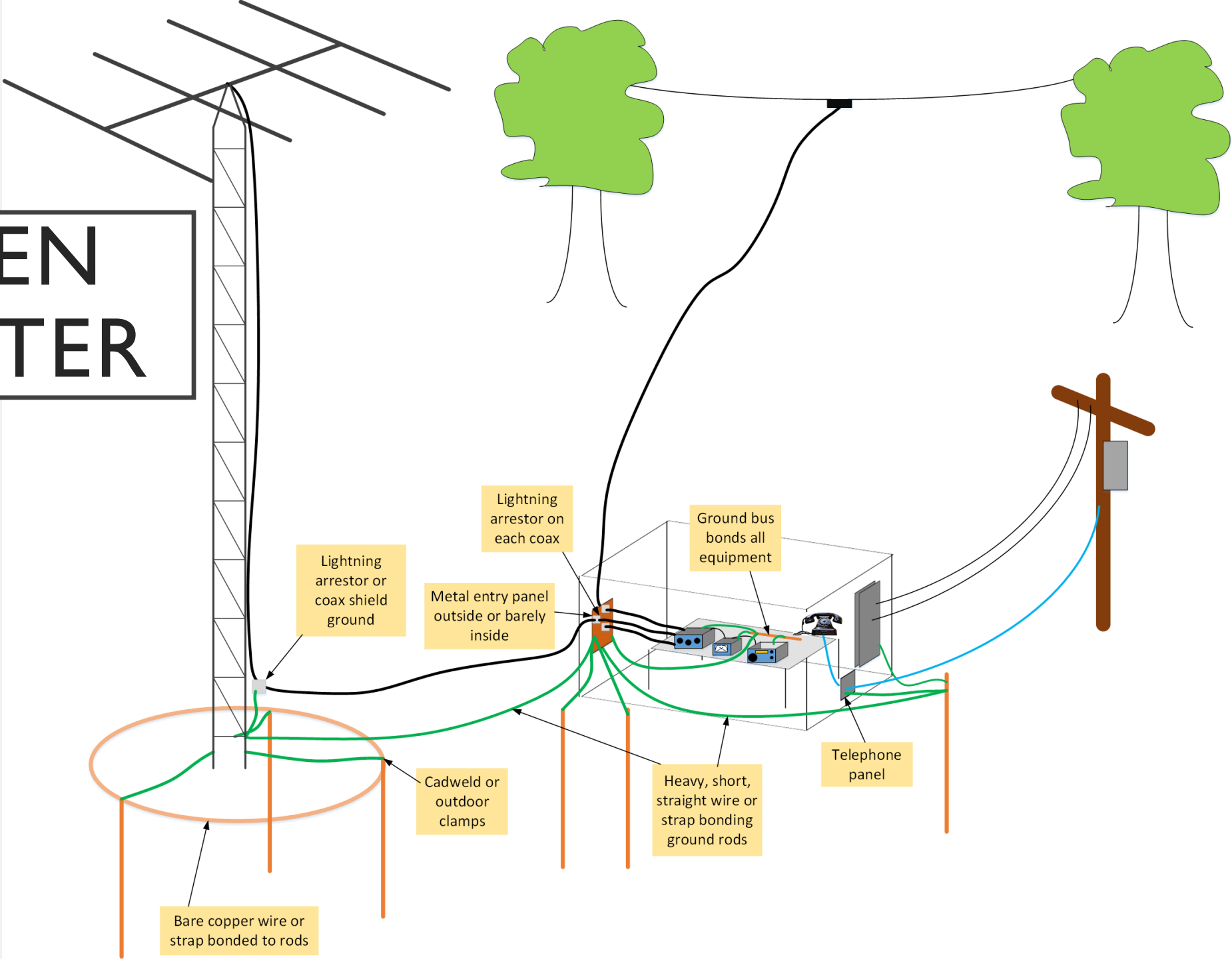
Metal entry panel outside or barely inside

Ground bus bonds all equipment

Heavy, short, straight wire or strap bonding ground rods

Make sure existing AC panel ground connections are good

**EVEN
BETTER**



THINGS TO AVOID

- Avoid braided strap
 - especially outdoors
- Little woven wires
- High impedance at RF & fast rise time pulses
- Ground connections that corrode and decay



If you *really* need to use braid, never ever ever use old coax shields

THINGS TO AVOID

- Avoid separate grounds with only your equipment, feedlines or the Earth connecting them
- Avoid sharp bends in ground wires (increases impedance)
- Corroded or loose connections



OUTDOOR GROUND CONNECTIONS

- Don't use regular solder on anything that will carry lightning current
 - lightning will melt it
- Acceptable:
 - Clamp with solid clamps and weatherproof
 - Inspect every year or two
 - Crimp and weatherproof
 - Silver Solder
 - Cad Weld (Exothermic welding)

SIDE TRIP TO “CADWELDING”

- I discovered this while installing my new tower
- It is the coolest thing ever
- Worth doing it just to see it in action

SIDE TRIP TO “CADWELDING”

- Two main vendors I found:
 - Erico
 - <https://www.dxengineering.com/parts/ero-gr1-161l>
 - Harger (my choice)
 - <http://www.kf7p.com/KF7P/HargerUniShot.html>
- About \$10-15 a shot
- + \$15 for putty
- + \$15 for a lighter

EXOTHERMIC WELDING



**Clean & Prep ground rod & wire
Put crucible over ground rod**



Make sure wire is through

EXOTHERMIC WELDING



EXOTHERMIC WELDING



EXOTHERMIC WELDING

- Before you ignite:
- You'll be melting powered metal at over 2,500° F
 - Surface of the sun is about 10,000°F
- Be prepared to move away





Video is hosted here on Youtube:

<https://youtu.be/v-yxteLUPLQ>

EXOTHERMIC WELDING

- Ignition above 1650°F
 - Safe to handle
- Process above 2500°F
- After the crucible cools (maybe 30 minutes), break it off with a hammer and dispose of it
- The result is wires welded onto the ground rod



THAT'S ALL FOLKS!

Questions and constructive comments:



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@johnwag

Complaints:

complaints@dev.null

Thanks!

REFERENCES

- <https://www.w8ji.com/> - Lots of good, correct info
- <http://www.arri.org/grounding-and-bonding-for-the-amateur> – Book with practical theory and ideas by H. Ward Silver, NOAX
- Motorola’s R56 “Standards and Guidelines for Communications Sites” (Google the PDF)
- Polyphasor’s Media Library:
<https://www.polyphaser.com/services/media-library/white-papers>