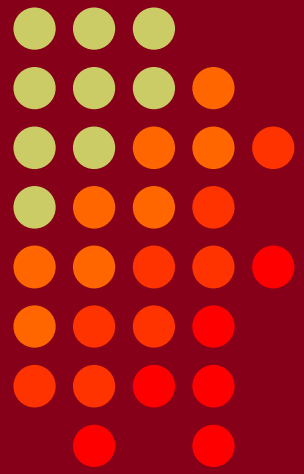
CTU PRESENTS

Grounding and Bonding For HF Contest Stations

Ward Silver NØAX

Thanks to Contest University and Icom America



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Goals of the Presentation

- Understand “ground” and “bond”
- Appreciate the different requirements for lightning protection and RF management
- Discuss issues for HF contest stations
- Common system satisfies all requirements
- Provide comprehensive resources

- Note – this in-person talk is an excerpt of the full talk with all slides in the CTU book

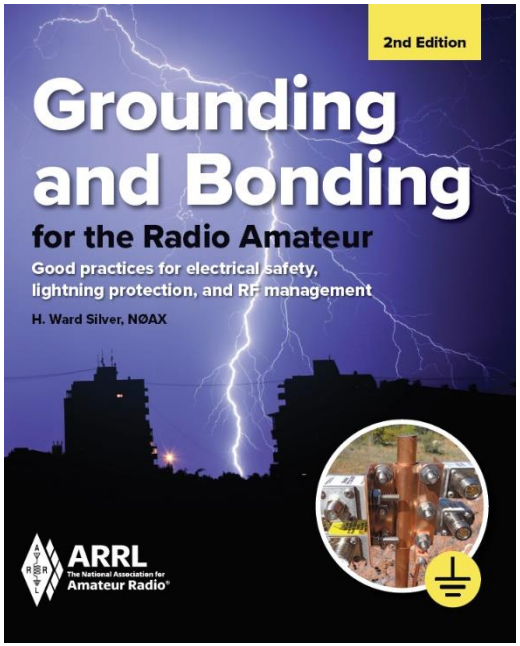
Ham Radio References

- *ARRL Handbook, ARRL Antenna Book*
- *NEC Handbook* – at your library
- *Lightning Protection for the Amateur Station* (Ron Block, NR2B – Jun/Jul/Aug 2002 *QST*) – ARRL website
- *Power, Grounding, Bonding, and Audio for Amateur Radio* and *RFI, Ferrites, and Common Mode Chokes For Hams* – available at **k9yc.com/publish.htm**
- W8JI website (**w8ji.com/ground_systems.htm**) and for mobile stations KØBG website (**k0bg.com**)

Background References

Grounding and Bonding for the Radio Amateur, 2nd Edn

- Covers AC wiring, lightning protection, and RF management
- Reviewed by a number of experts, including the ARRL Lab
- Numerous examples for you to use



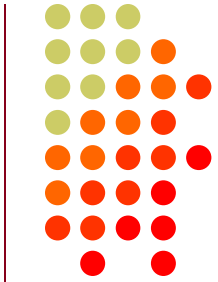
What *IS* "Ground" Anyway

- "Ground" has different meanings
  - Noun - an "earth connection" (ac, lightning) or a local reference potential (circuits, RF)
  - Verb - an action "to connect to the reference potential"
  - Adjective - a type of connection, such as a "ground conductor" or "ground system"
- It can mean *all of these things at the same time*
  - "I'm grounding the chassis to ground with a ground wire."

What *IS* "Ground" Anyway

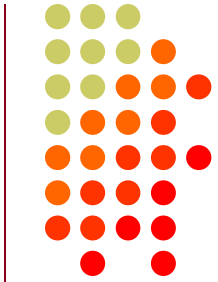
- The Earth is NOT – a magic sink into which we can pour RF or lightning and expect it to magically and safely disappear (same for the vehicle body)
- Fuzzy definitions:
  - "RF ground" – ain't no such thing, only local reference potential
  - "Ground loops" – not the problem you think they are
  - "Single-point ground" – depends on frequency
- Each set of requirements uses "ground" differently

What *IS* “Bonding” Anyway



- Bonding is a connection intended to keep two points at the same voltage
  - Everything goes up and down **TOGETHER**
  - Prevents shock hazards from voltage differences
  - Prevents destructive voltage differences caused by lightning surges
  - Limits current between devices caused by voltage differences from RF pickup

What *IS* “Bonding” Anyway



- Sounds hard but it’s not
- Sounds expensive but it’s not
- Requires the right connecting materials and hardware
- Works in your favor for ac safety, lightning protection, and RF management

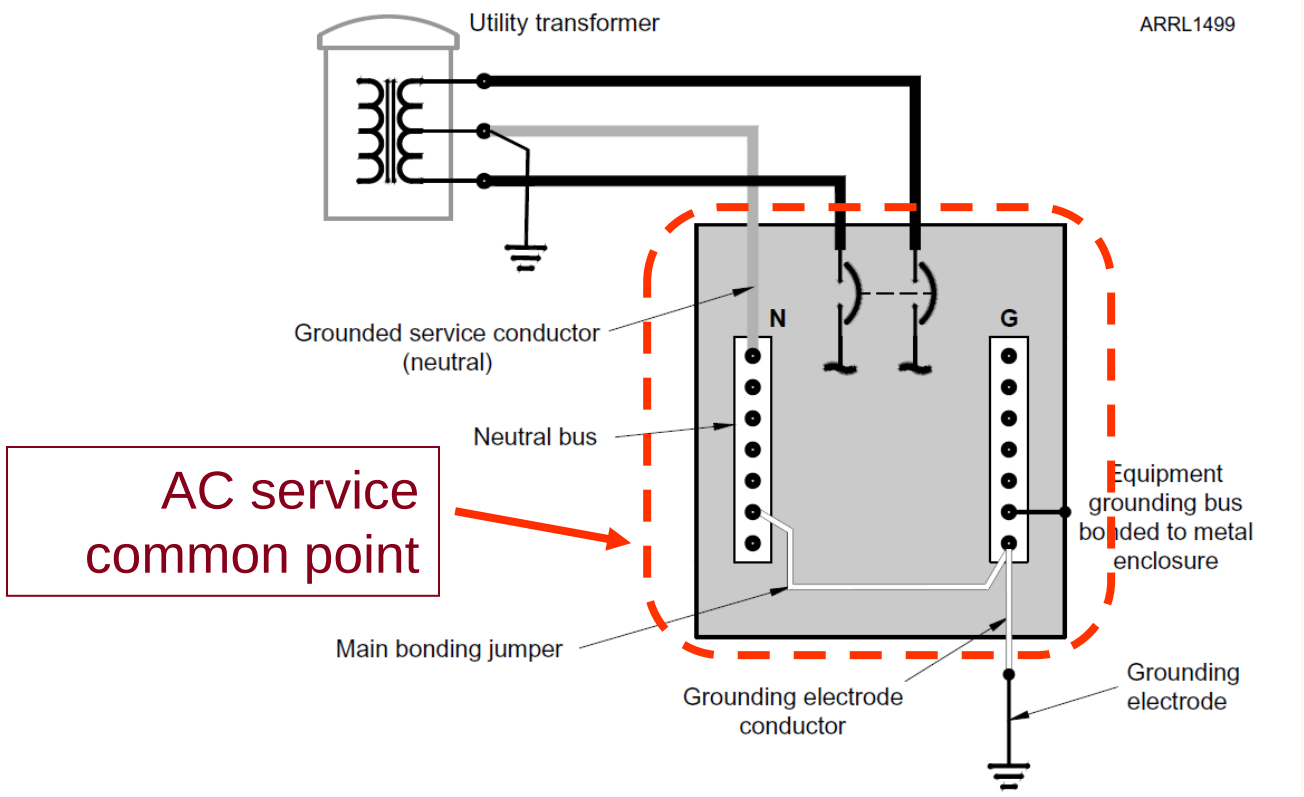
What *IS* "Bonding" Anyway

- For bonding to work, it has to be…
  - Low-Z and "short" at the frequencies of interest
  - Heavy enough to carry the expected current
  - Sturdy enough to survive the environment
- In the ham station, use…
  - Strap (20 ga) or heavy wire (#14 or larger)
  - Flat-weave, tinned braid if equipment moves around (mobile stations, particularly)
    - Exposed braid from old coax deteriorates
    - Protect braid from moisture and chemicals

AC Safety Grounding

- Grounding for ac safety has several names
  - “Equipment ground”, “third-wire ground”, “green-wire ground”
- Keep ground connections low-resistance
- Purpose is two-fold
  - Provides a path to ac common point for fault current (shorts, leakage)
  - Earth connections stabilize the ac power system voltage during faults or transients, such as lightning

AC Safety Grounding



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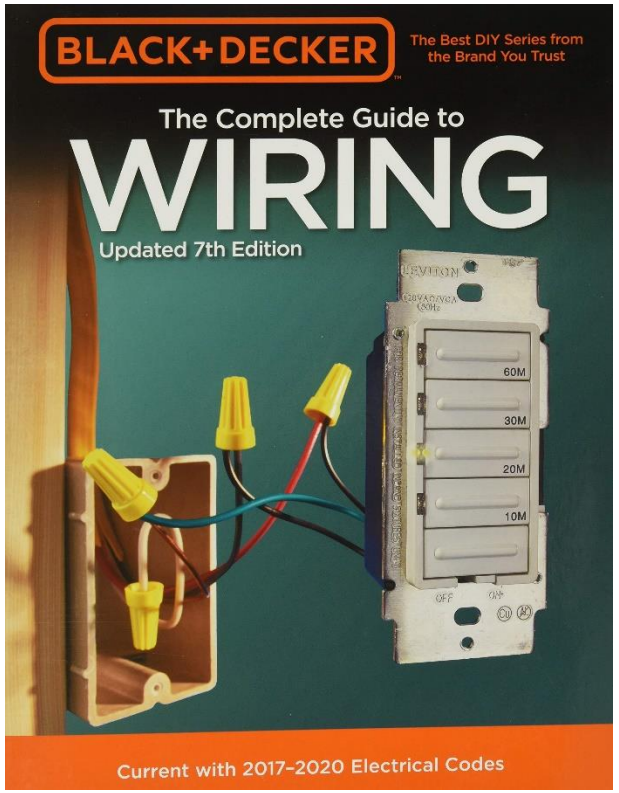
AC Safety Grounding

- If you aren't sure you know what you're doing…get a how-to reference
- Follow rules for sub-panels and outbuildings
- Hire a pro electrician to do the work or inspect yours
- Local code is the law



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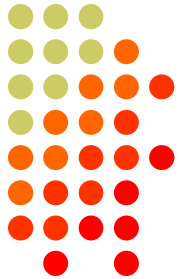
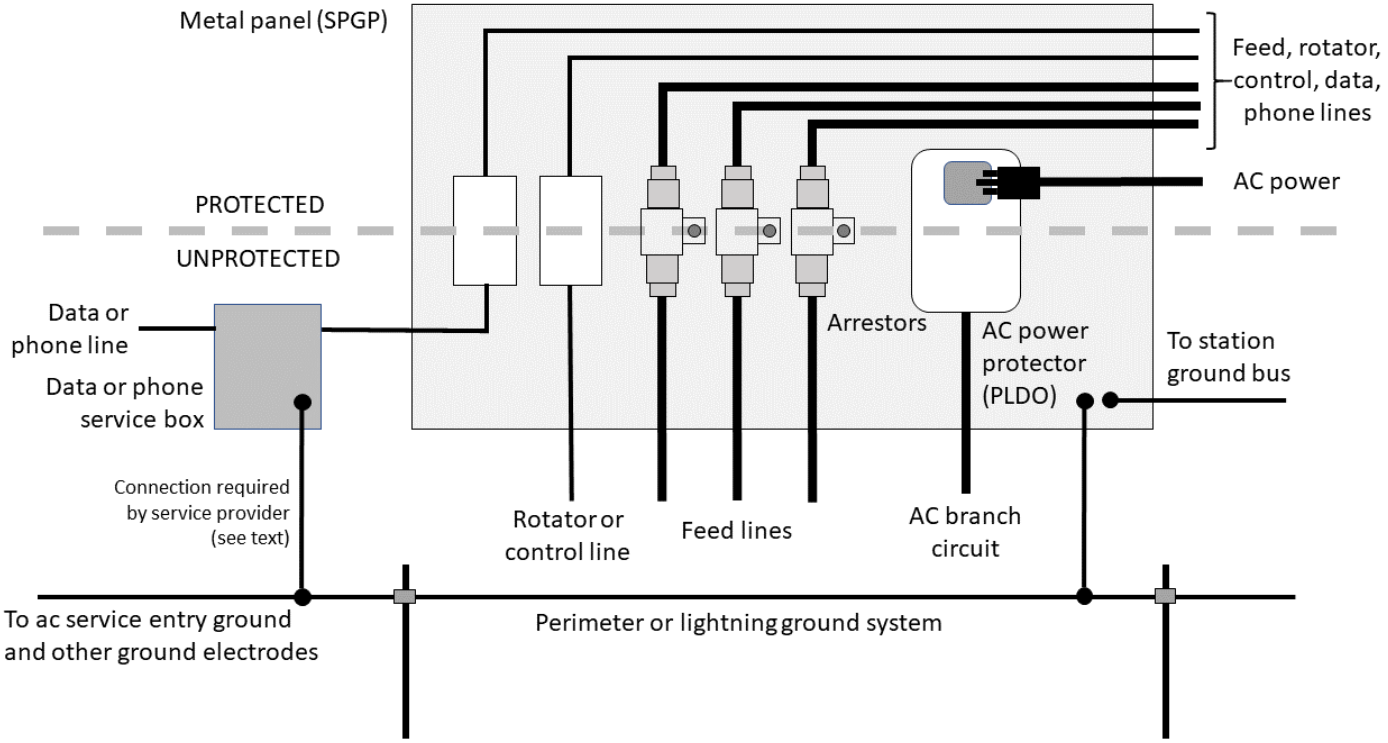
Lightning Protection



- You can't steer lightning, but…you *can* help lightning make "good decisions"
  - Heavy, direct paths to the Earth to dissipate charge in the ground
  - Inductance is more important than resistance
  - Paths should be *outside* your residence
  - Don't make it easy for lightning to go <u>through</u> your station on its way to the Earth

Lightning Protection

- Single-point Ground Panel (SPGP)



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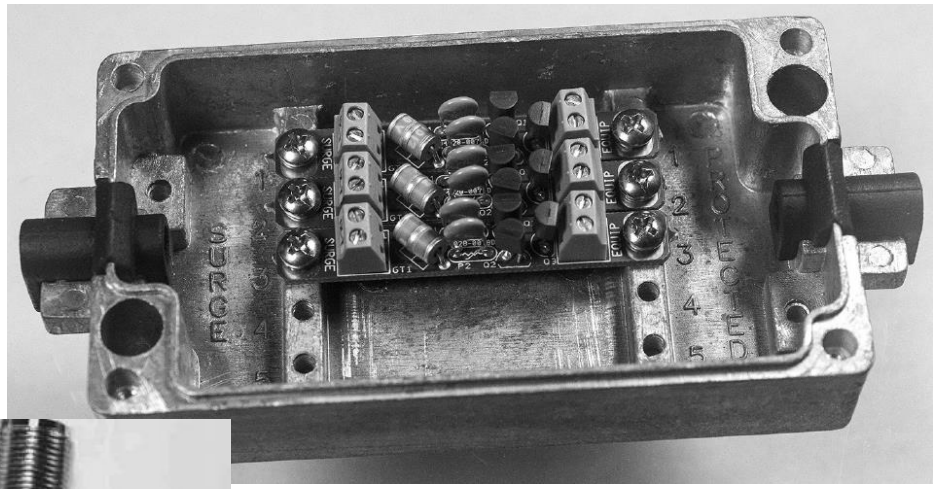
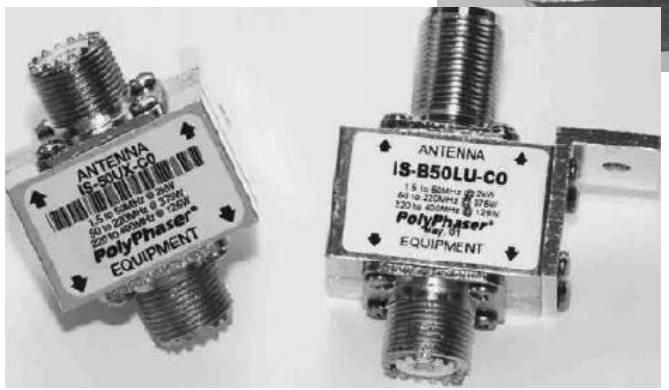
Lightning Protection





Lightning Protection

- Single-Point Ground Panels
  - Bonds grounds of all entry paths
    - Connected to perimeter ground
  - All protectors “fire” at the same time
    - Minimize voltage differences due to transient timing
  - Includes non-RF and AC power
  - Keep protected and unprotected cables separated

Lightning Protection

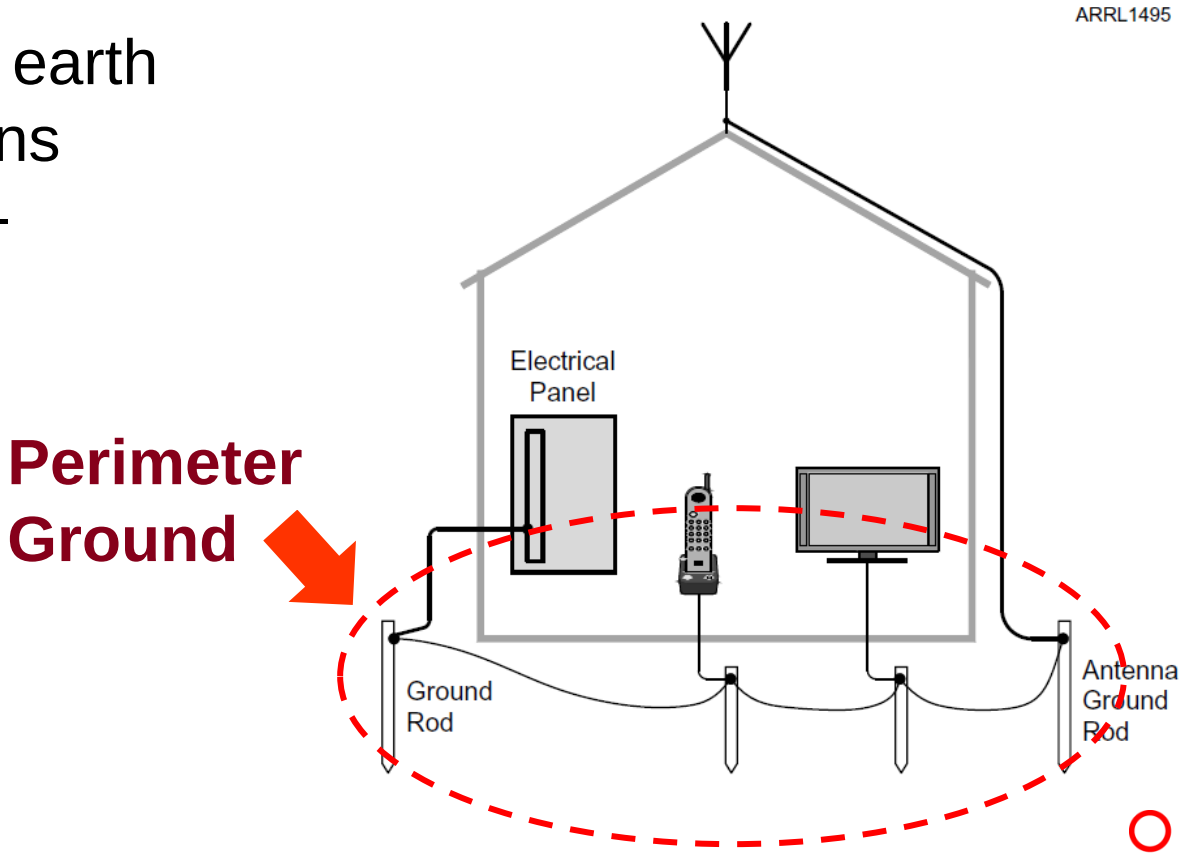
- Single-point Ground Panel (station entry)

Lightning Protection

- Single-point Ground Panel (in station)

Lightning Protection

Bond ALL earth connections together – required!



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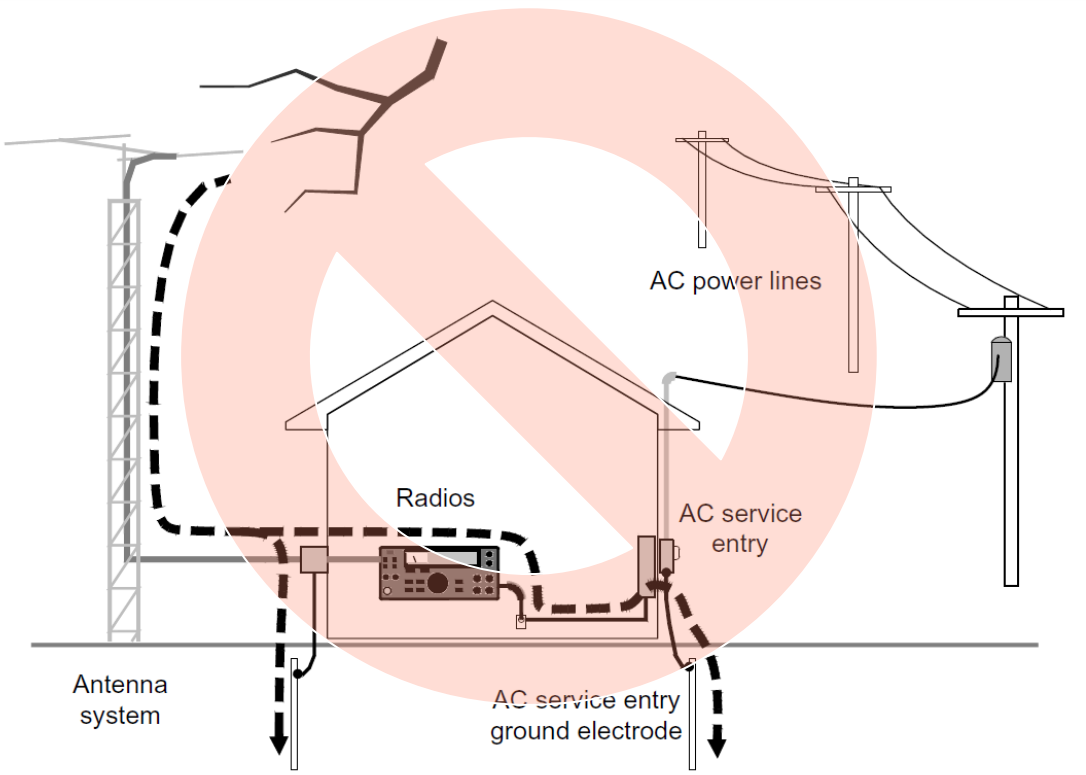
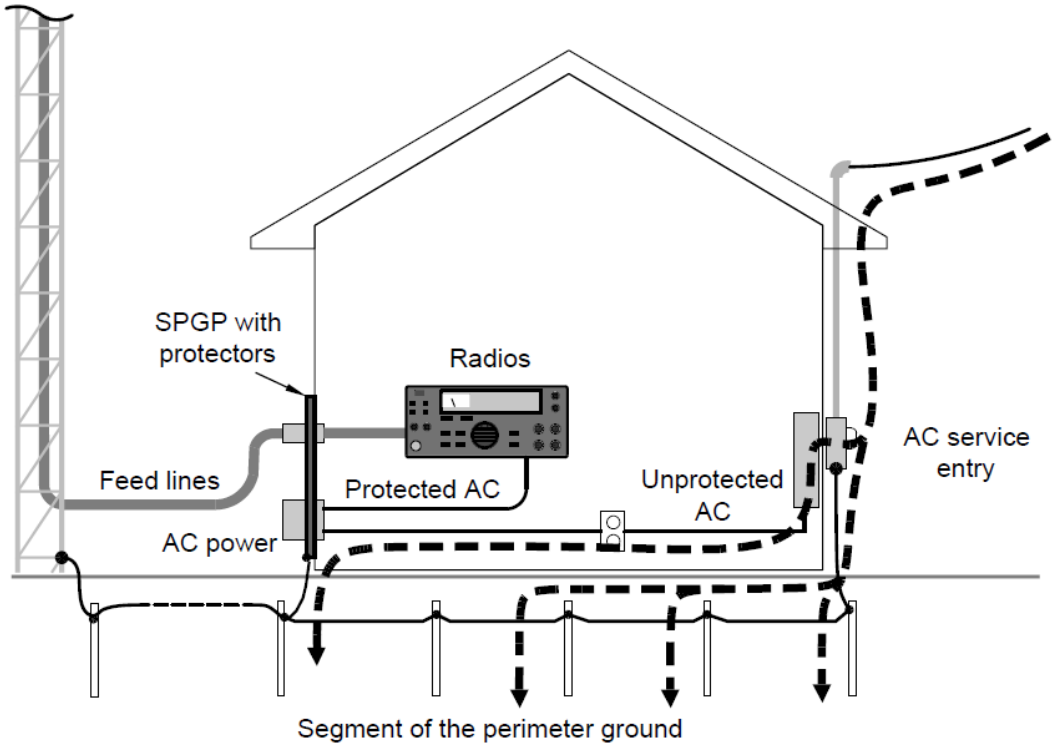
Lightning Protection

- Don’t create low-impedance paths *through* your station



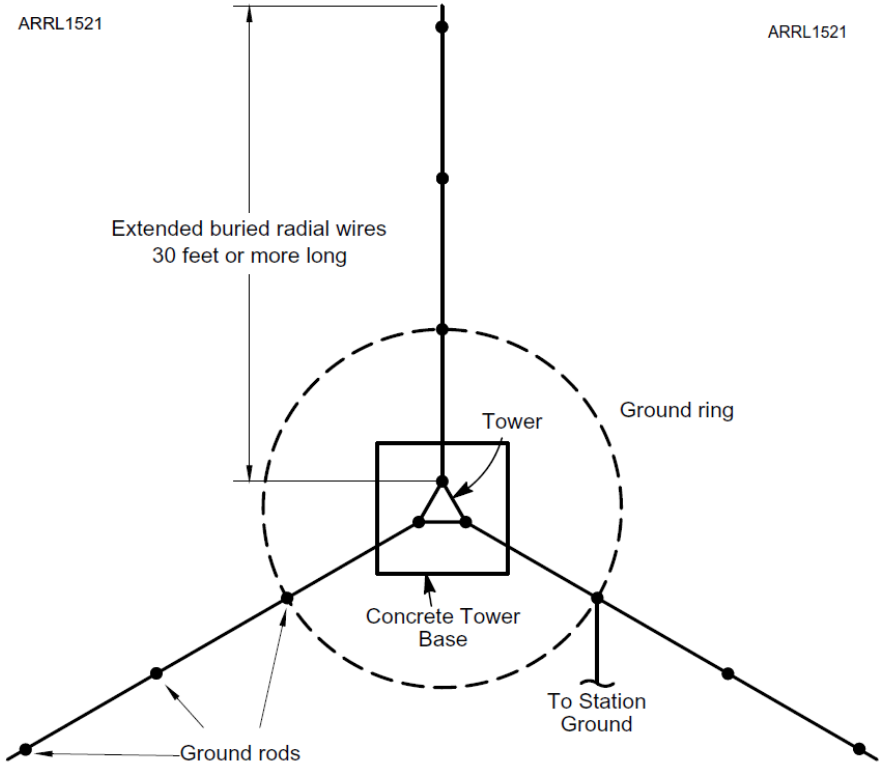
Lightning Protection

- Ground paths should go *around* your station



Lightning Protection

- Rods and radials
- Bond feed lines to the tower every 50 feet



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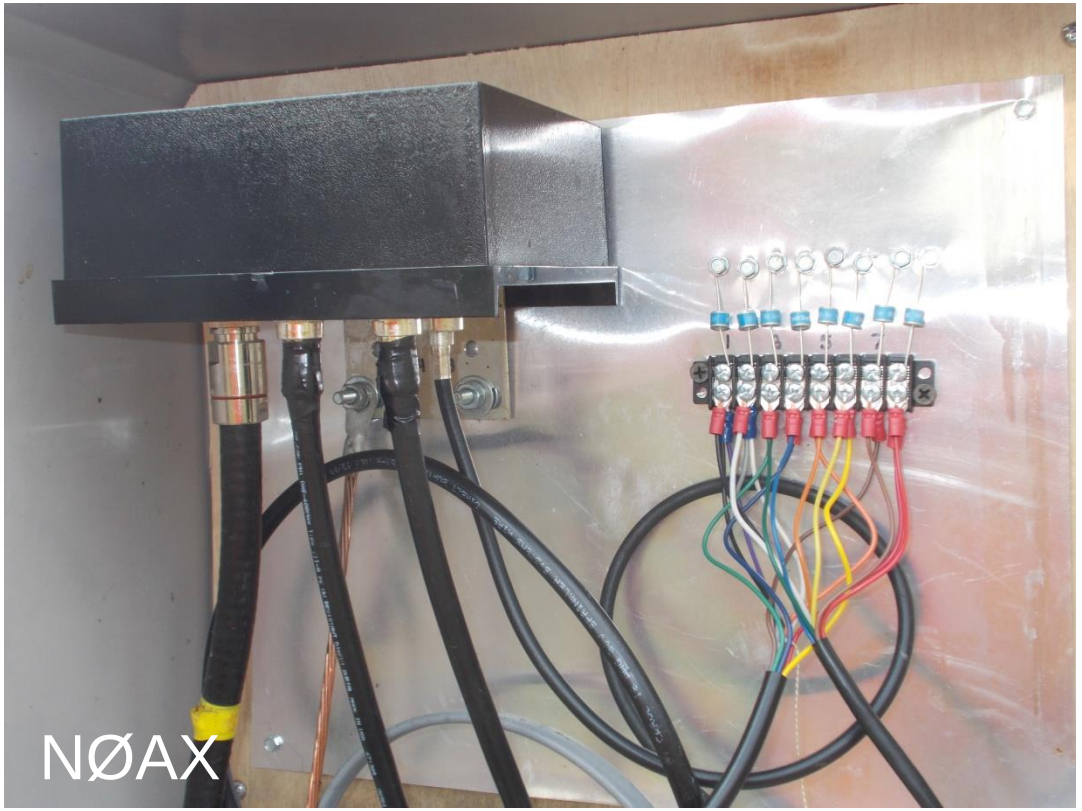
Lightning Protection

- Bond feed lines to the tower

- Spark gaps

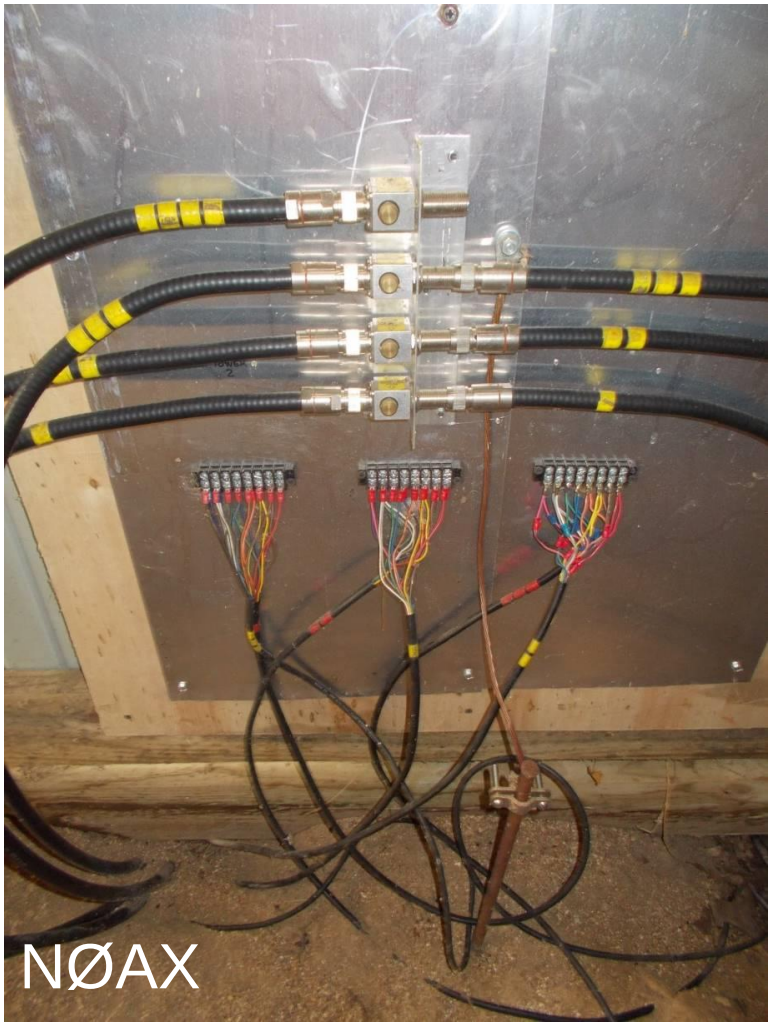
Lightning Protection

- Single-point Ground Panel (tower base)



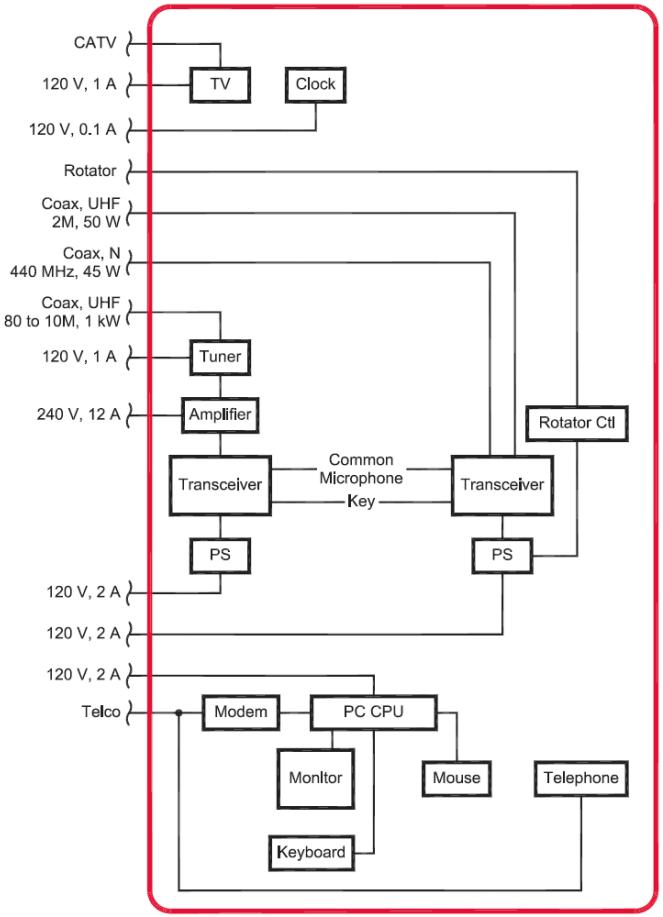
Lightning Protection

- Single-point Ground Panel



Lightning Protection

- Ron Block NR2B's 2002 *QST* articles
- Protected Zones
  - Every line crossing the boundary ***must*** be protected by a common or bonded ground connection
  - Bond equipment within the station



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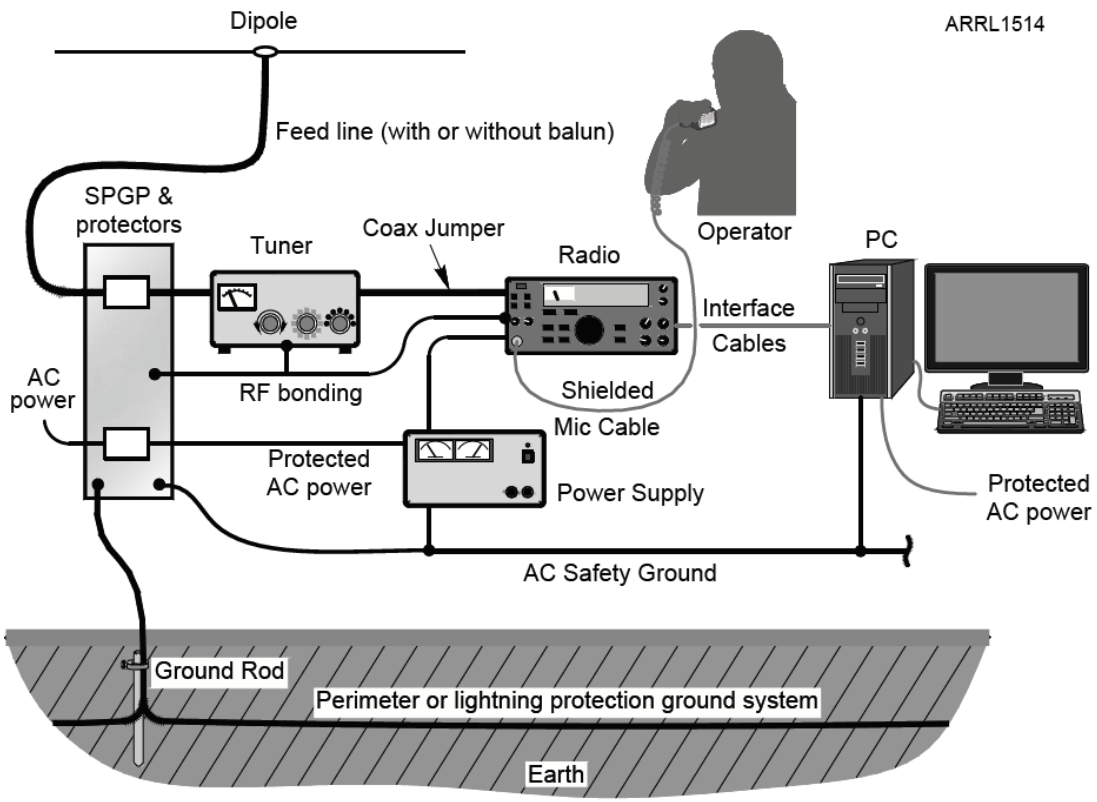
RF Management

- Everything in the station is an antenna

RF Management

- ***EVERYTHING!***



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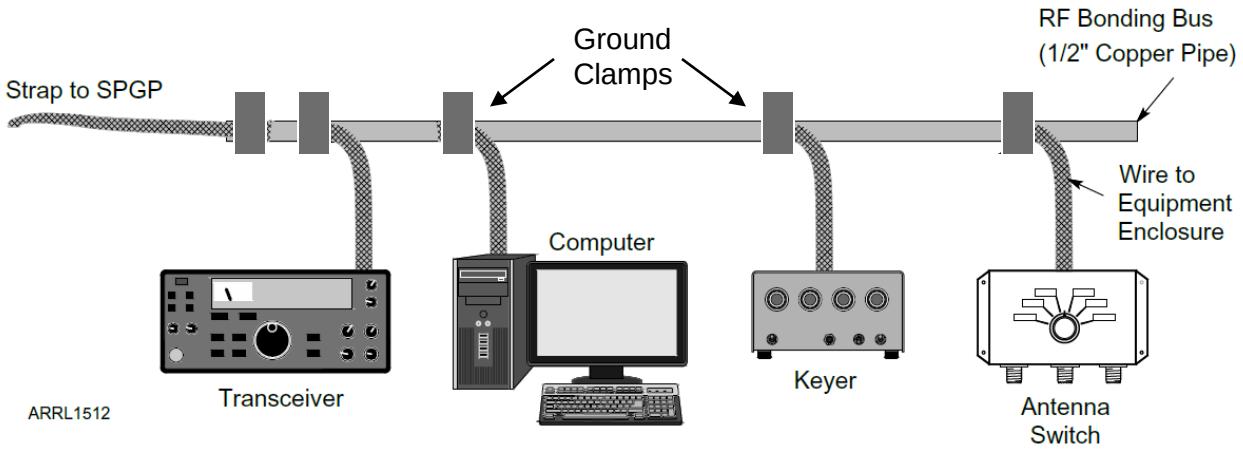
RF Management

- Everything in the station is an antenna
- Forget about an all-band “RF ground”
  - Concentrate instead on bonding
  - Keep connections *electrically short*
  - Keep everything at the SAME voltage
- Amplifiers = high RF field strength
  - Requires extra attention to bonding
- Create common reference plane and/or bus

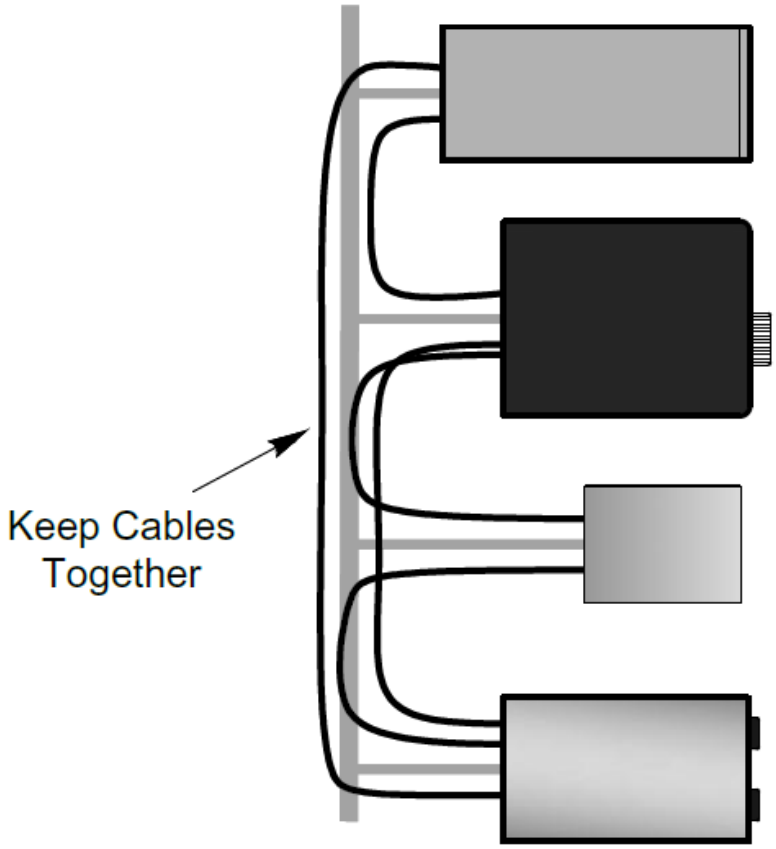
RF Management

- Bonding inside the station
  - Eliminates “hot spots”, reduces “buzz” and hum
  - Reduces RFI from common-mode current
  - Reduces sensitivity to physical configuration



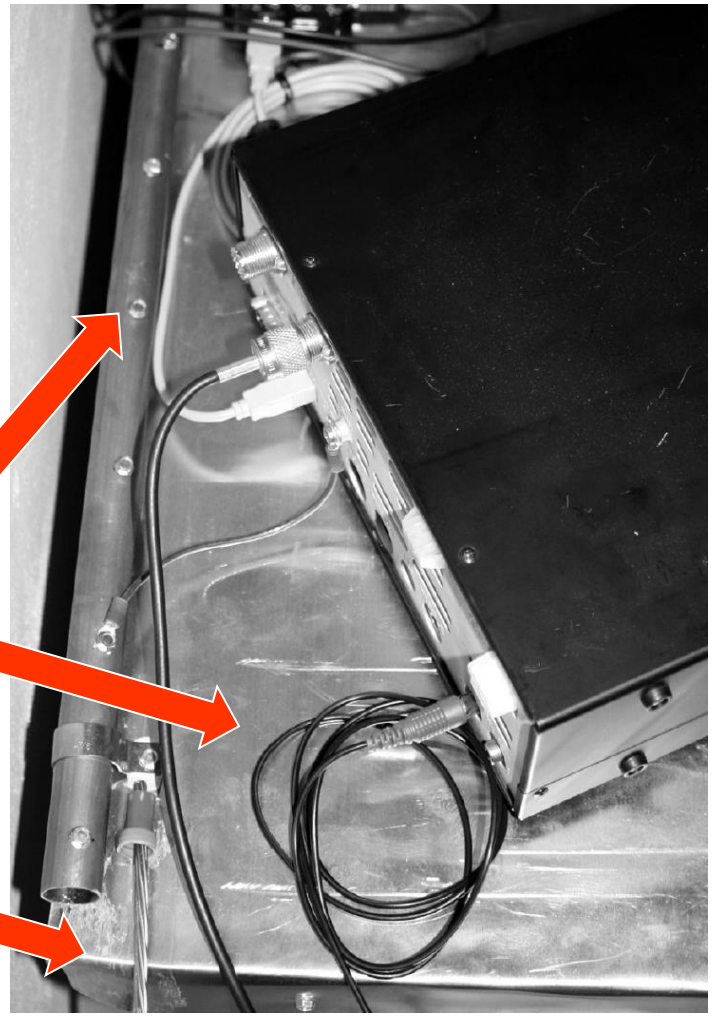
RF Management

- Minimize loop area and cable length
- Short or coiled cables
- Use a bonding bus and reference plane
- Use shielded cables
- Short straps or wires



RF Management

- RF ground plane
- Sheet of metal
- Helps equalize voltage
- Run cables along the ground plane
- Bond to station ground system



RF Management

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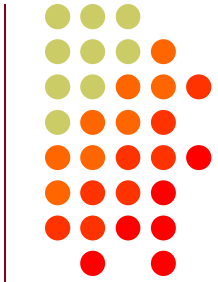
Ground System Review



- A single, solid ground system made of short, heavy, direct connections can satisfy all of the requirements for…
  - AC Safety
  - Lightning Protection
  - RF Management & Clean Audio
- Bond all grounds, keep protectors together
- Perimeter ground helps keep lightning currents outside the building
- All currents flow on all wires

The Mobile Station

- RF issues can be more intense – you're IN the antenna!
- Special power wiring considerations
- Bonding and the vehicle body
- Mounting antennas

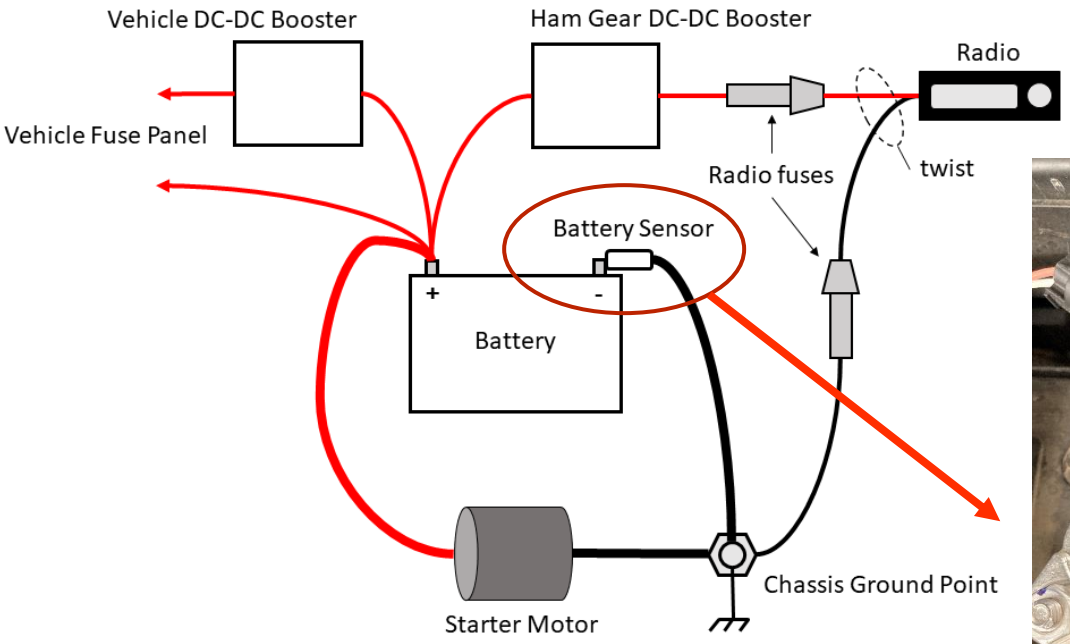
Mobile Power

- Fusing, Ampacity, Voltage Drop
- Power return and Battery Monitoring System
- RF pickup
- DC-DC Boosters

Fusing, Ampacity, Voltage Drop

- Fuses in BOTH leads – ALWAYS
- Adequate rating of power connection
  - Power sockets in the vehicle not sufficient
- Power wiring must be adequately sized
  - Max R = Max V drop / Max I
  - 0.5 V / 25 A = 0.02 Ω
  - 20 feet of #10 AWG wire
- Mobile radios need at least 11 V and usually more
- Don’t forget connector resistance!

Power Return Connection



Battery Management Systems (BMS)

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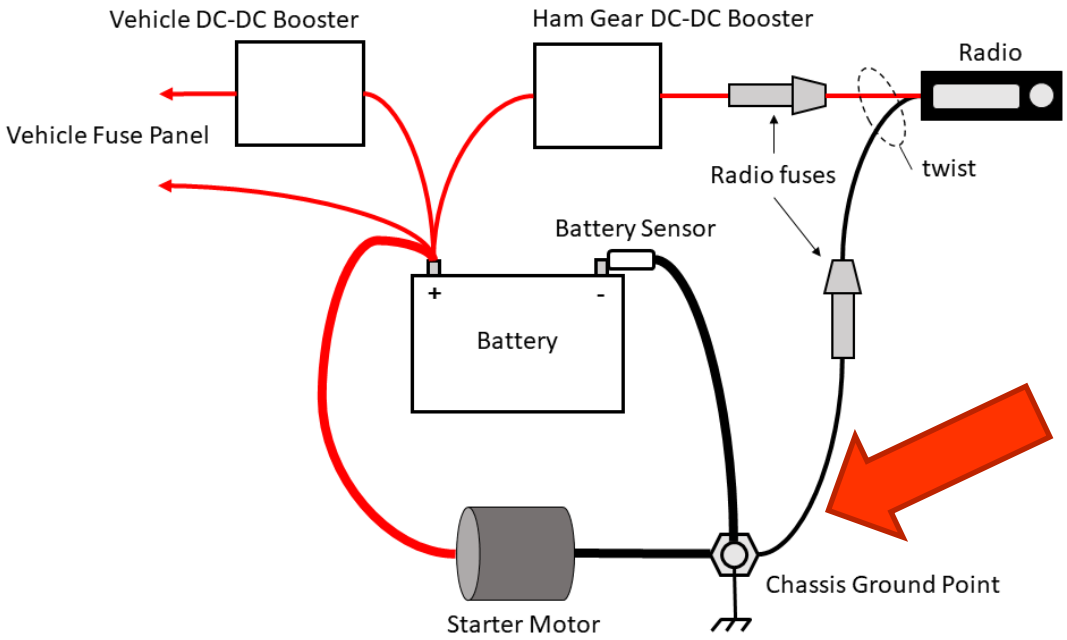
Power Return Connection



Connect dc return here – NOT to the negative battery terminal

"Home-run wiring"

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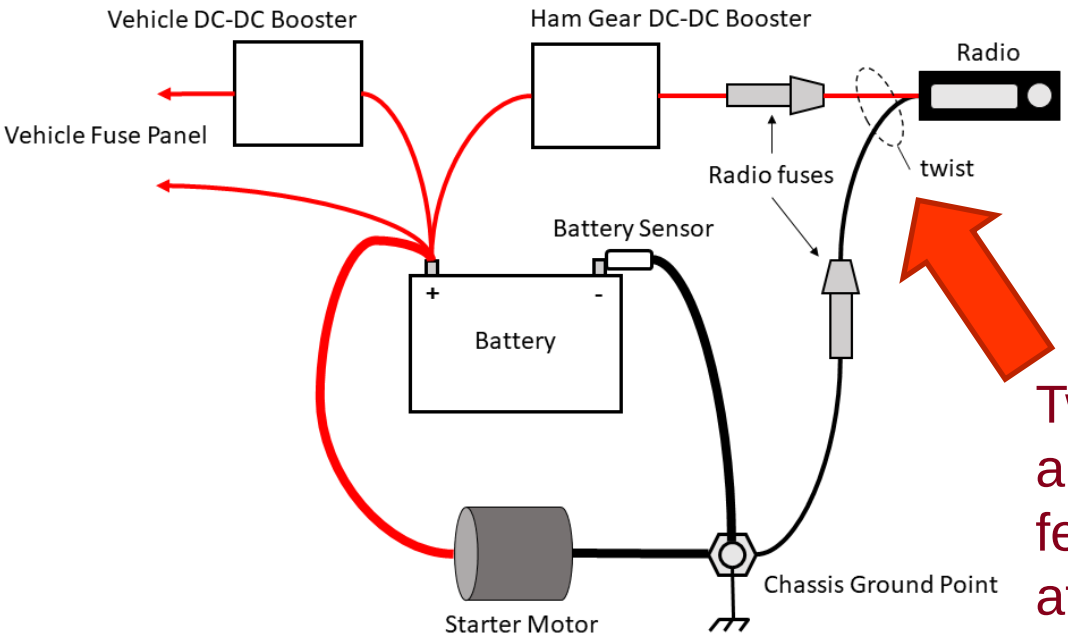
Power Return Connection



Twist wires and install ferrite cores at the radio to reduce RF pickup

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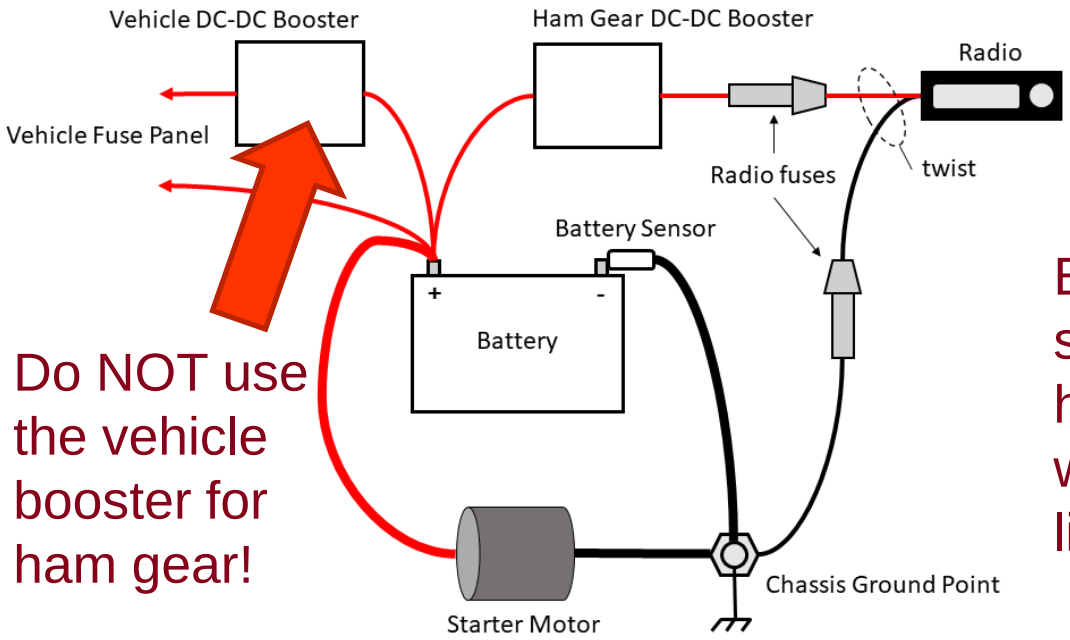
DC-DC Boosters



Do NOT use the vehicle booster for ham gear!

Boosters should use home-run wiring just like radios

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Bonding in Mobile Stations

- Body components not always well-bonded or even metallic!
- Don’t use sub-system ground points
  - Intermittent dc voltage drops
  - Can upset sub-system operation
- Bonding to body creates new return and RF paths
- Protect connections with anti-corrosion compound designed for vehicle use

Mounting Equipment

- Single pieces of gear don’t need bonding
- Body panel is part of the antenna system
  - May require isolated sub-panel mount
- Don’t bond control head to body

Mounting Equipment

- Standalone mini-racks
- Truck toolboxes
- Carry-case stations
- Security issues
- Bond internally
- No need for vehicle bond

Mounting Equipment

- Mechanical security is paramount
- Watch out for air bags!
- Use channels under trim strips
  - Helps shield from direct RF pickup
  - Protects cables
- Watch out for hidden wiring!
- Service bulletins and repair manuals may help

Mounting Antennas

- Bond to body *AT* the antenna
  - Through-panel NMO probably the best
  - Lip mounts need additional body bond at HF
  - Beware of paint and coatings!
- Mag-mounts don't work well at HF
  - Insufficient body coupling (100 pF per magnet)
  - Coax shield is part of the antenna – causes RFI
  - Need extra body bond wire (also part of antenna)
- Decouple at the antenna and at radio

Buying and Planning

- Upfit packages
- Fleet sales and re-sales
- Service department guidance
- Manufacturer's service bulletins
- Car audio and two-way radio shops

ARE WE DONE YET?
(almost…)

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Additional Resources

- Professional Associations and Companies
  - National Fire Protection Association (**www.nfpa.org**)
  - International Association of Electrical Inspectors (**www.iaei.org**)
  - Mike Holt Enterprises (**www.mikeholt.com**) — training and continuing education for electricians, many tutorials
  - Polyphaser (**www.polyphaser.com/resources/white-papers**) — various papers and tutorials on lightning protection for communications facilities, including ham stations

Additional Resources

- Standards
  - *Standards and Guidelines for Communication Sites* (Motorola R56) – available online
  - *FAA Document on Practices and Procedures for Lightning Protection, Grounding, Bonding, and Shielding Implementation* — **www.faa.gov/documentLibrary/media/Order/6950.19A.pdf**
  - IEEE Std 1100 – 2006, *IEEE Recommended Practices for Powering and Grounding Electronic Equipment* — **www.ieee.org** (available from most libraries)
  - MIL-HDBK-419A – *Grounding, Bonding, and Shielding for Electronic Equipments and Facilities (Vol 1 and 2)* — **www.uscg.mil/petaluma/TPF/ET/_SMS/Mil-STDs/MILHDBK419.pdf**

Additional Resources

- Books and Online Material
  - Block, R. R., The “Grounds” for Lightning and EMP Protection, Second Edition, PolyPhaser Corporation, 1993.
  - Rand, K. A., Lightning Protection and Grounding Solutions for Communications Sites, PolyPhaser Corporation, 2000.
  - ARRL Technical Information Service sections
    - Electrical Safety — **www.arrl.org/electrical-safety**
    - Grounding (various types and topics) — **www.arrl.org/grounding**
    - Lightning Protection - **www.arrl.org/lightning-protection**

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