Grounding and Bonding For Home & Mobile HF Stations

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Thanks to Contest University and Icom America

Goals of the Session

- Understand “ground” and “bond”
- Appreciate the different requirements for ac safety, lightning protection, and RF
- Discuss issues and techniques for home HF stations
- Discuss special issues of mobile stations
- Common system satisfies all requirements
- Provide comprehensive resources

Who Is This Talk For?

- Home HF station owners…
  - Building a new station
  - Upgrading a small station
  - Adding an amp
  - In lightning country
  - Trying for better performance

Who Is This Talk For?

- Mobile HF station owners…
  - Installing a new station
    - Power wiring
    - Equipment bonding
    - Antenna and feed line issues
  - Dealing with RFI and noise

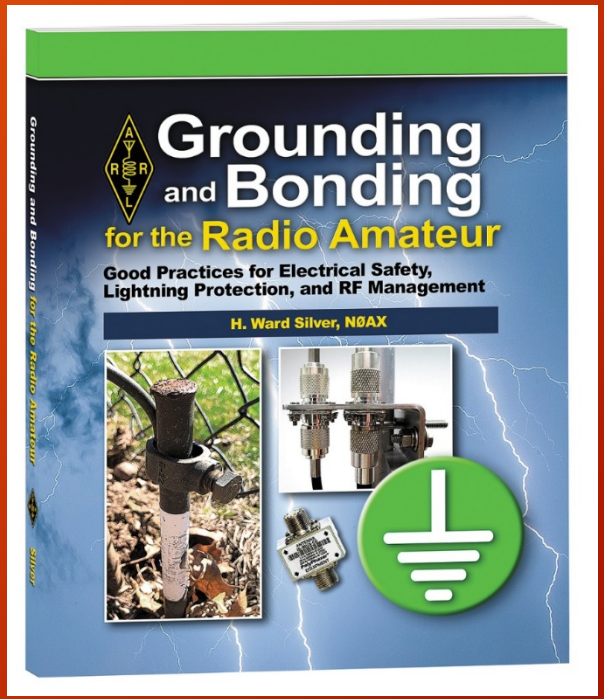
Ham Radio References

- *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

- 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
  - "Ground loops" – not the problem you think they are
  - "Single-point ground" – it depends…

What *IS* "Bonding" Anyway

- 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
  - Limit 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

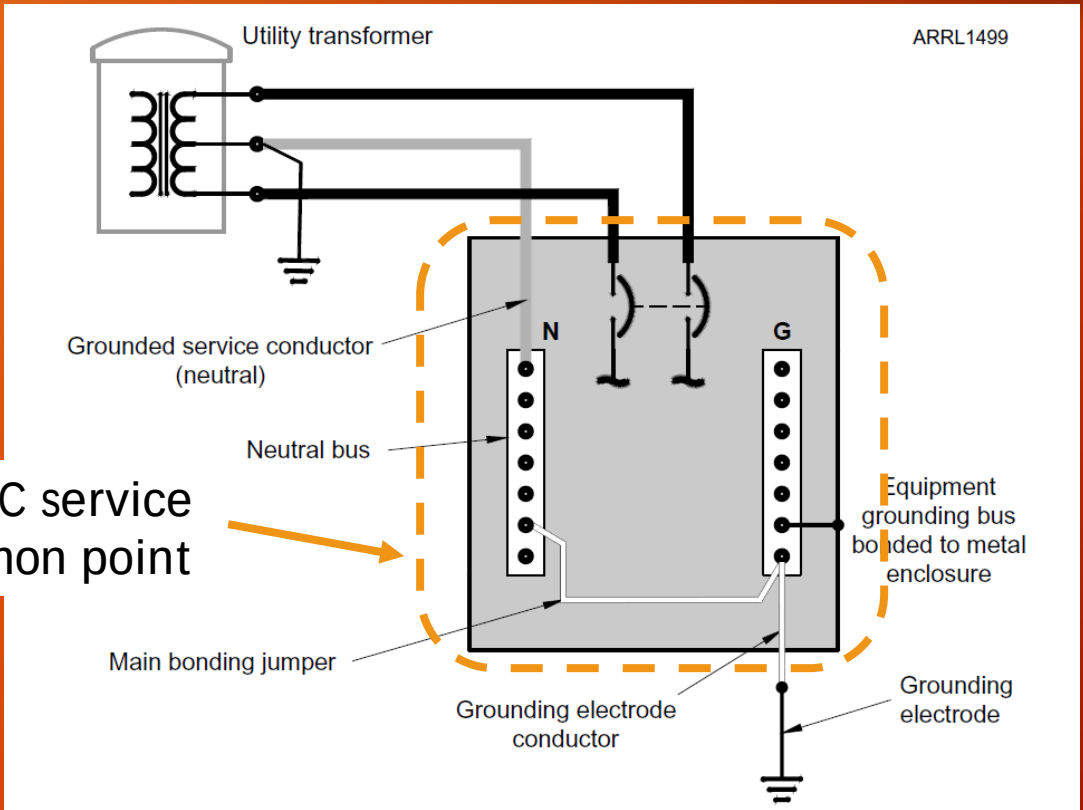
What *IS* "Bonding" Anyway

- 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
- For 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

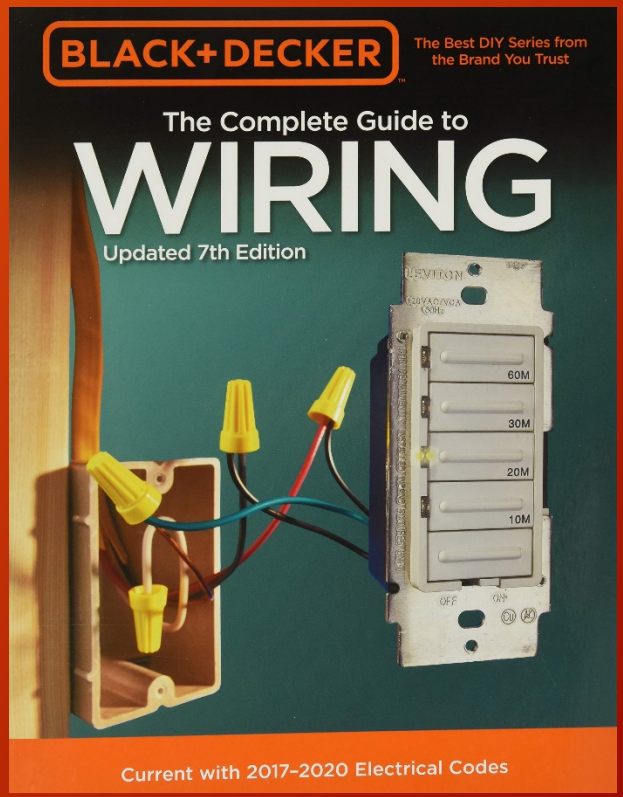
- Grounding for ac safety has several names
  - “Equipment ground”, “third-wire ground”, “green-wire ground”
- Keep ground connections low-resistance
- Purpose is two-fold
  - Provides a path to ac common point for fault current (shorts, leakage)
  - Stabilizes the ac power system voltage during faults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

AC Safety Grounding



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

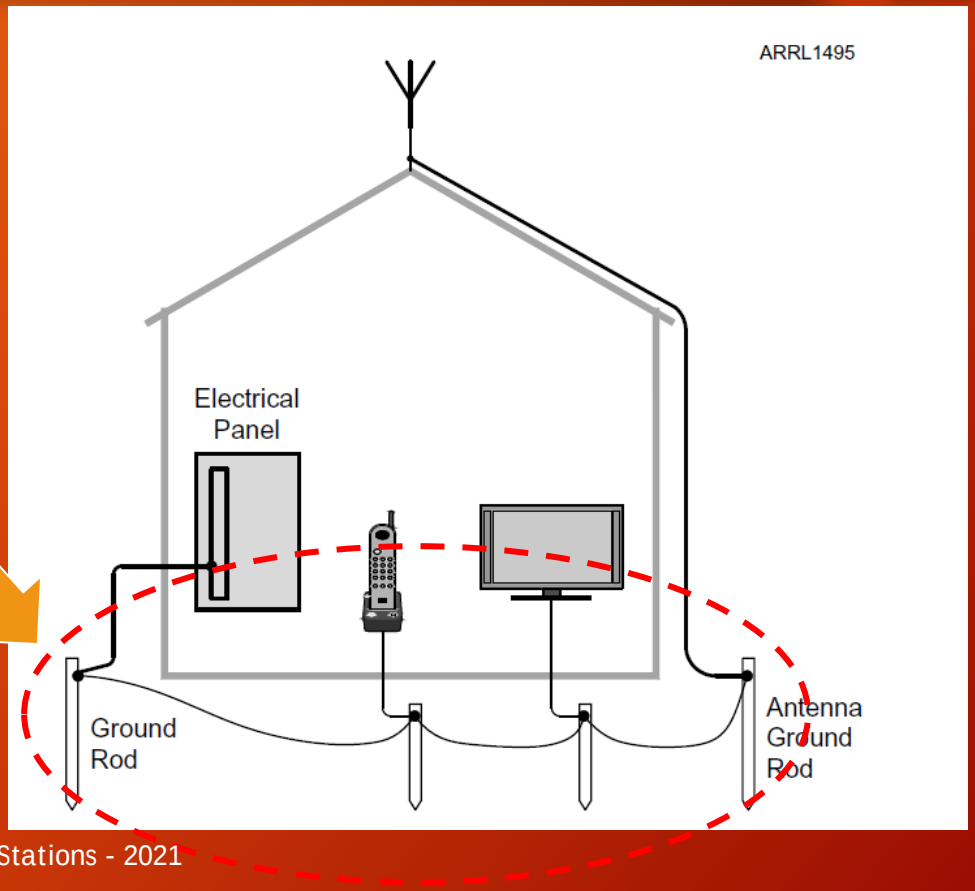


Lightning Protection

- 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

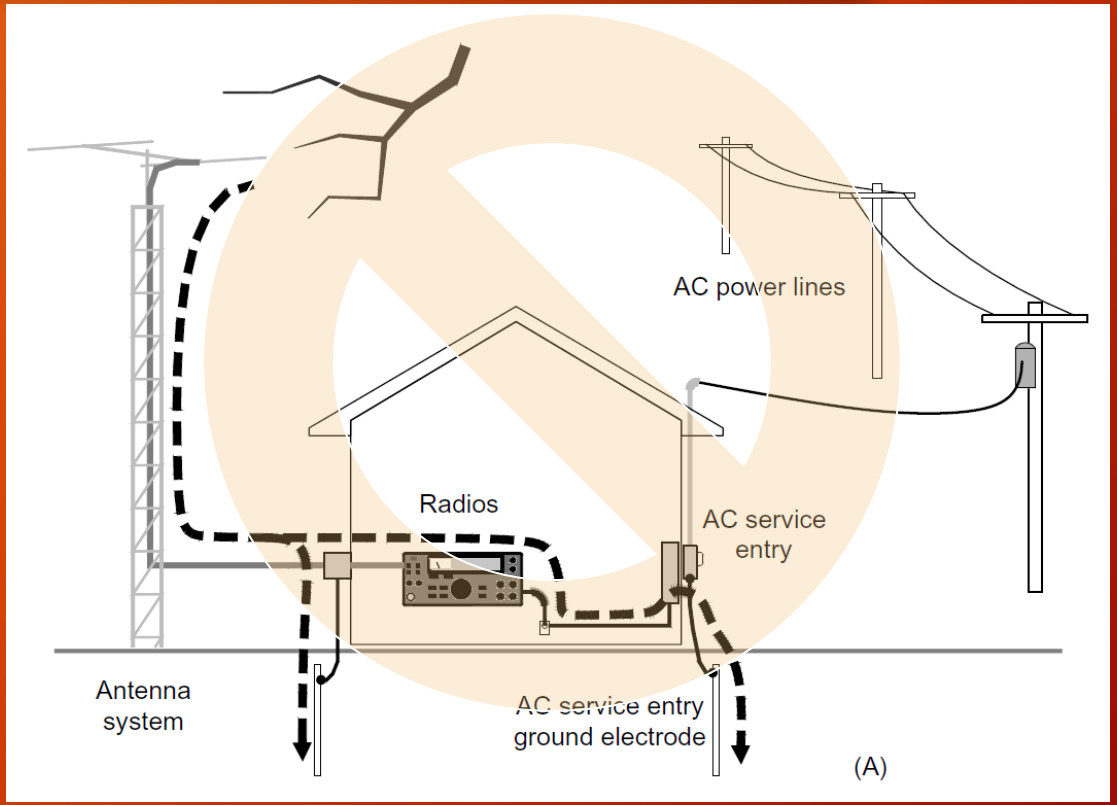
Lightning Protection

Bond ALL earth connections together



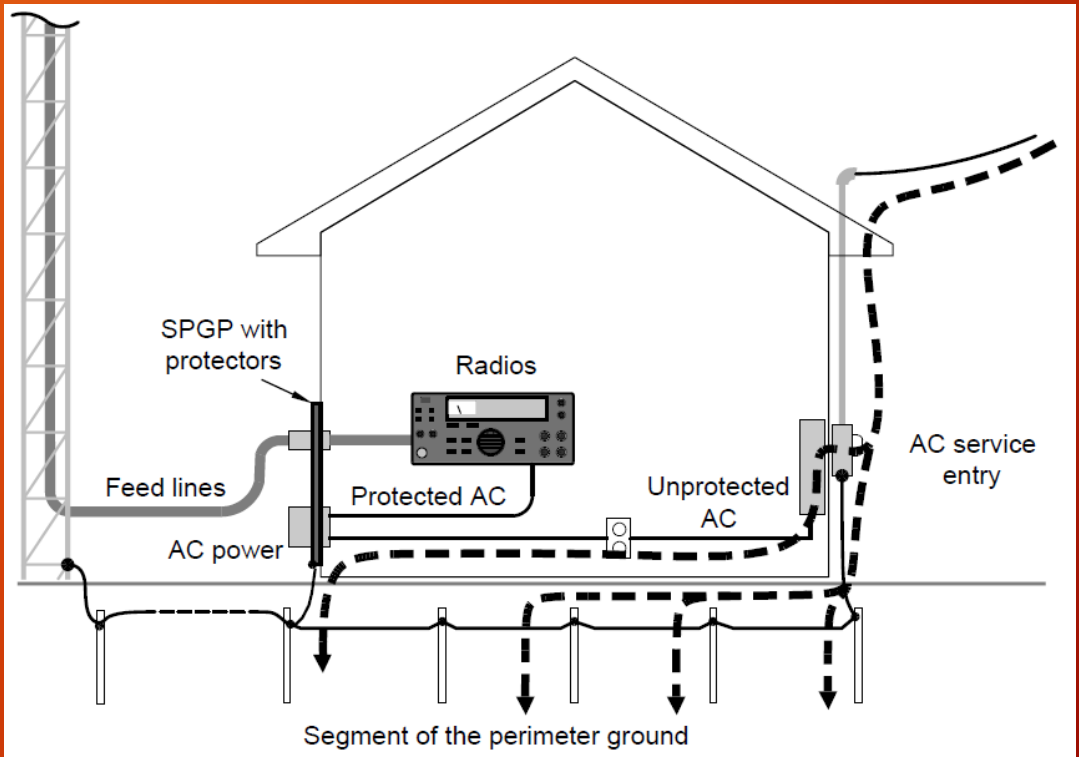
Lightning Protection

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



Lightning Protection

- Ground paths should go *around* your station

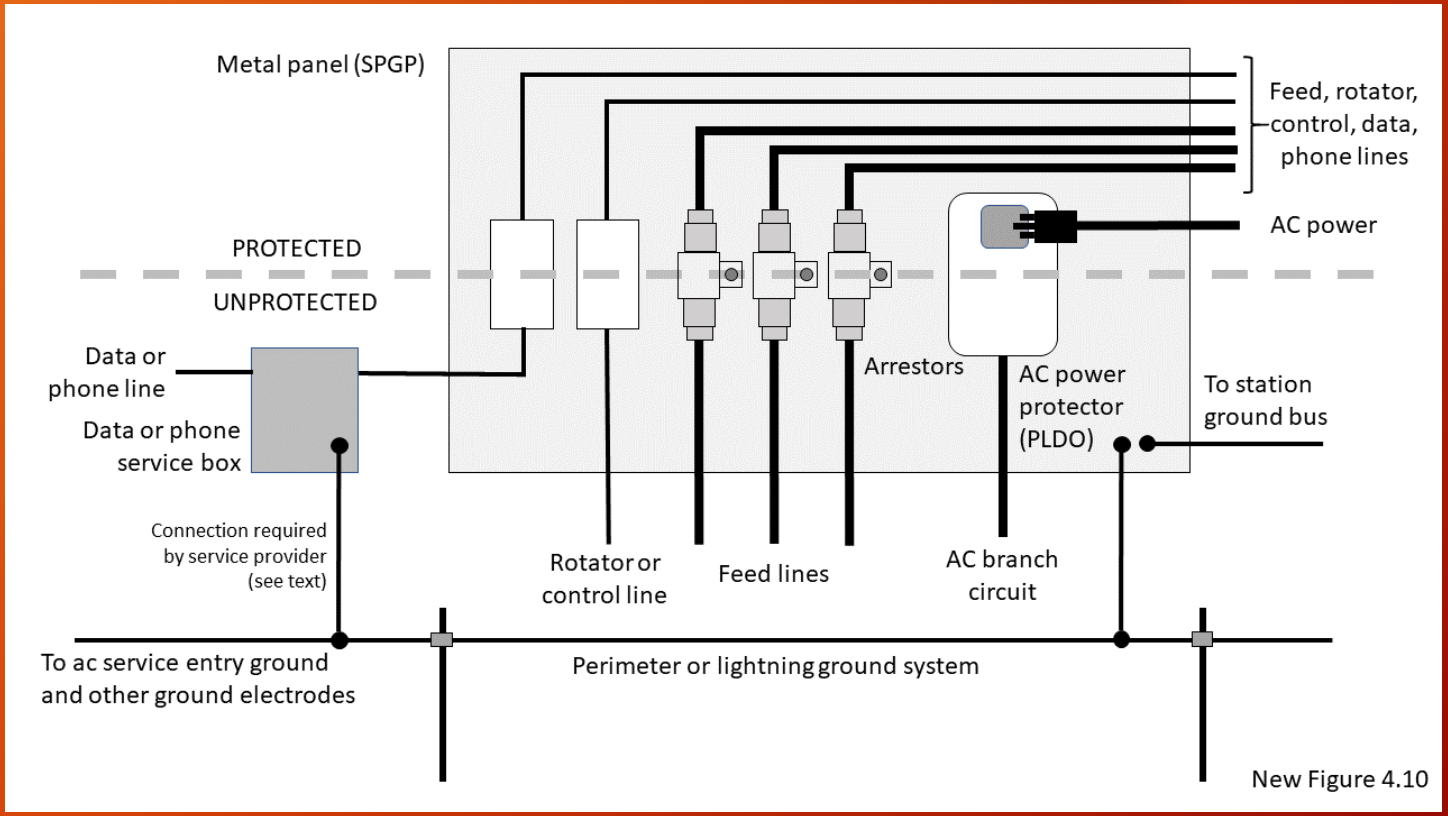


Lightning Protection

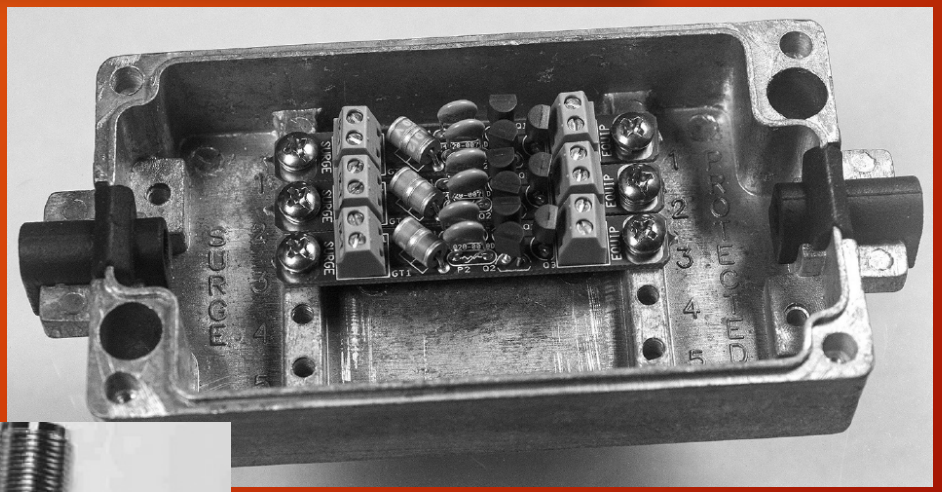
- Rods and radials
- Bond feed lines to the tower every 50 feet
- Spark gaps for insulated base towers

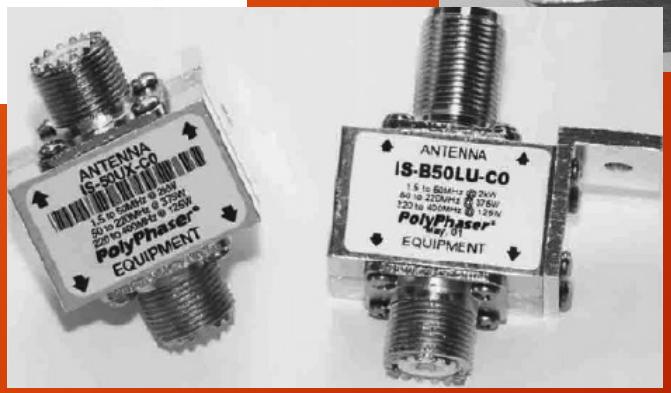
Lightning Protection

- Single-point Ground Panel (SPGP)



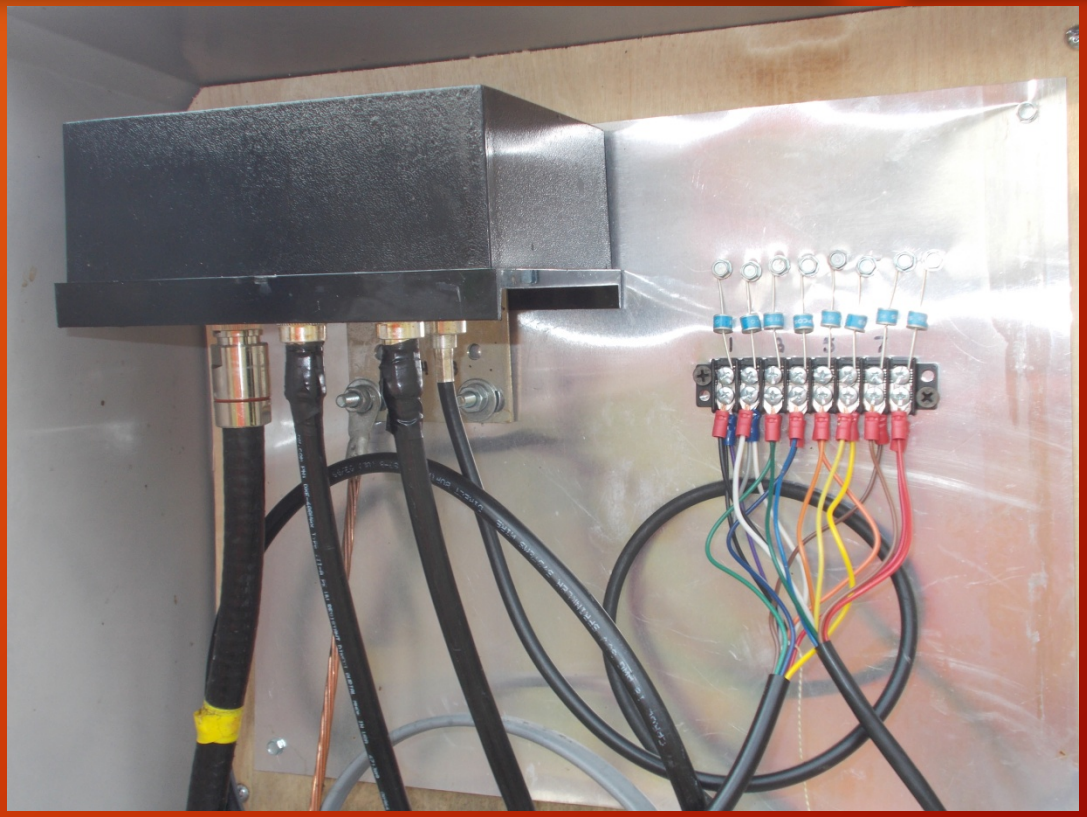
Lightning Protection





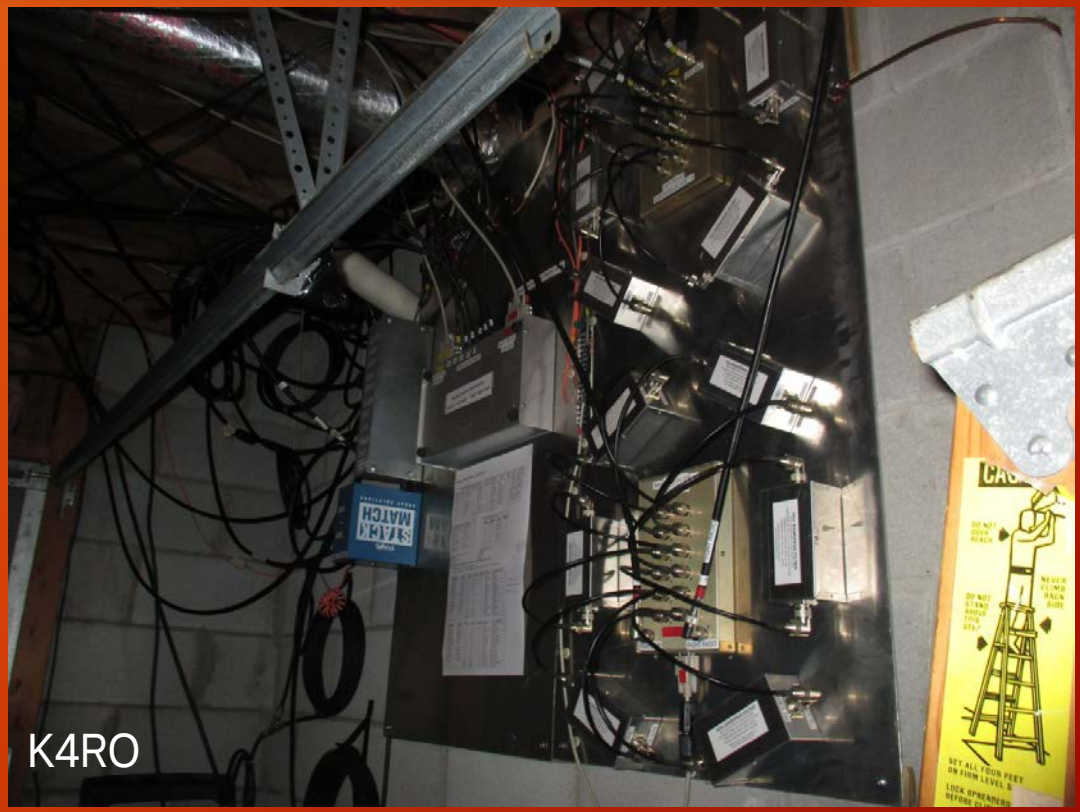
Lightning Protection

- Single-point Ground Panel (tower base)



Lightning Protection

- Single-point Ground Panel (station entry)

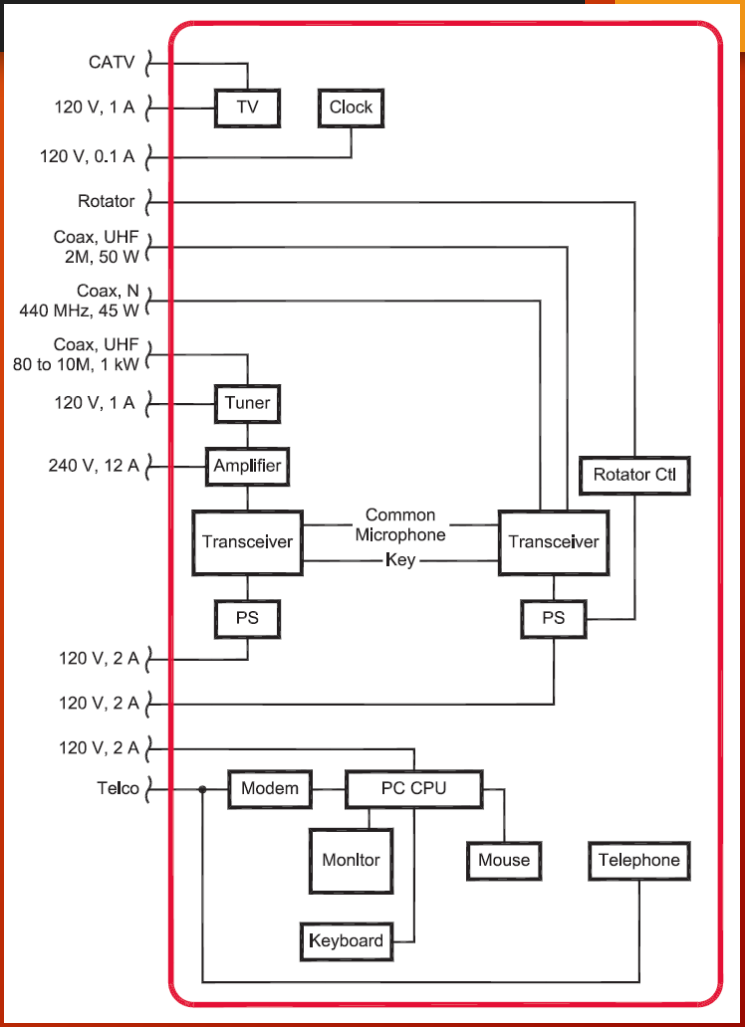


Lightning Protection

- Single-point Ground Panel (in station)

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

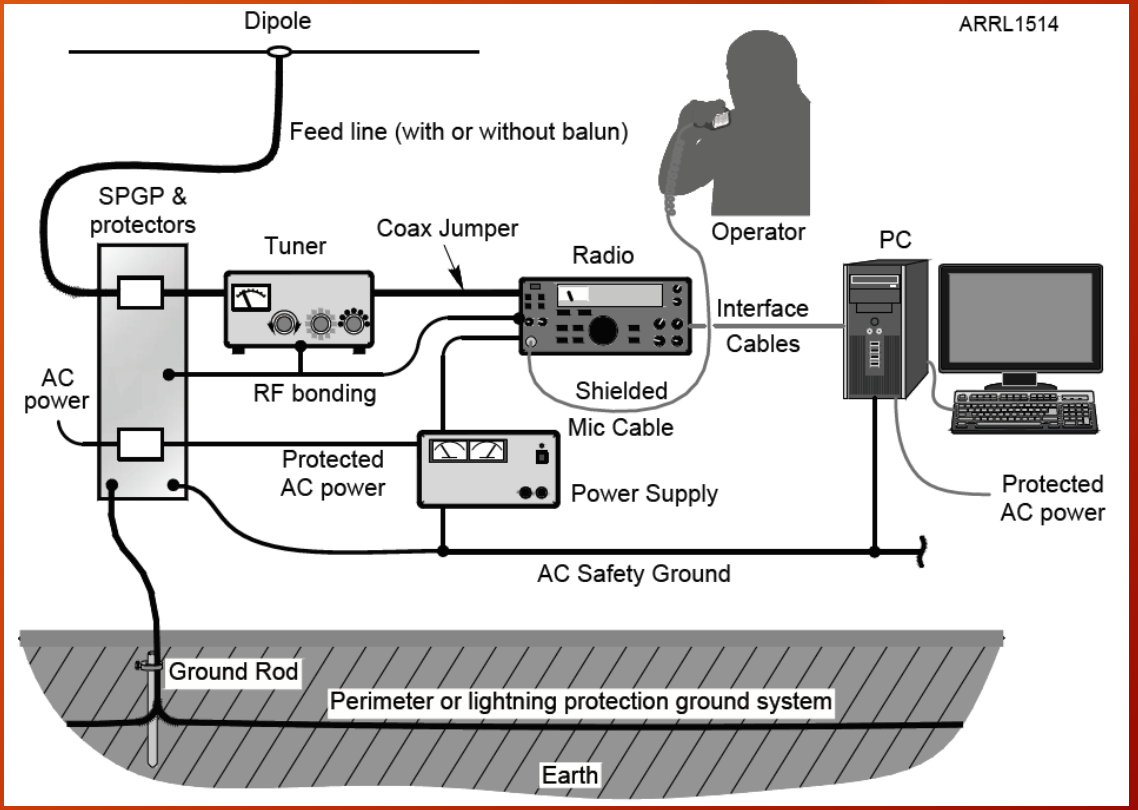


RF Management

- Everything in the station is an antenna

RF Management

- ***EVERYTHING!***

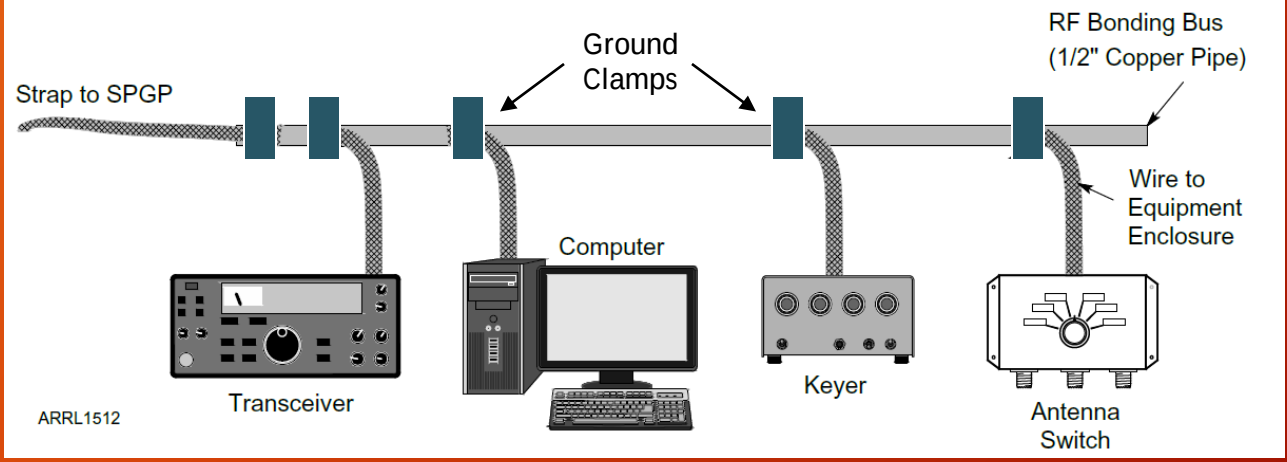


RF Management

- Everything in the station is an antenna
- Forget about an "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

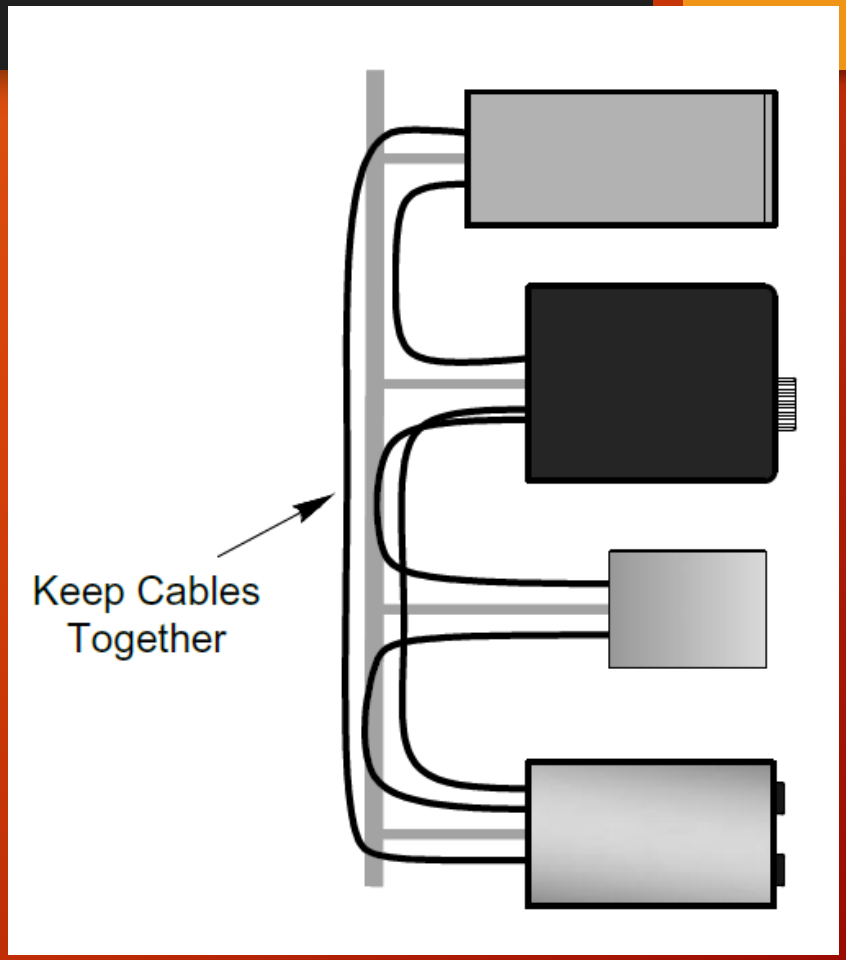
RF Management

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

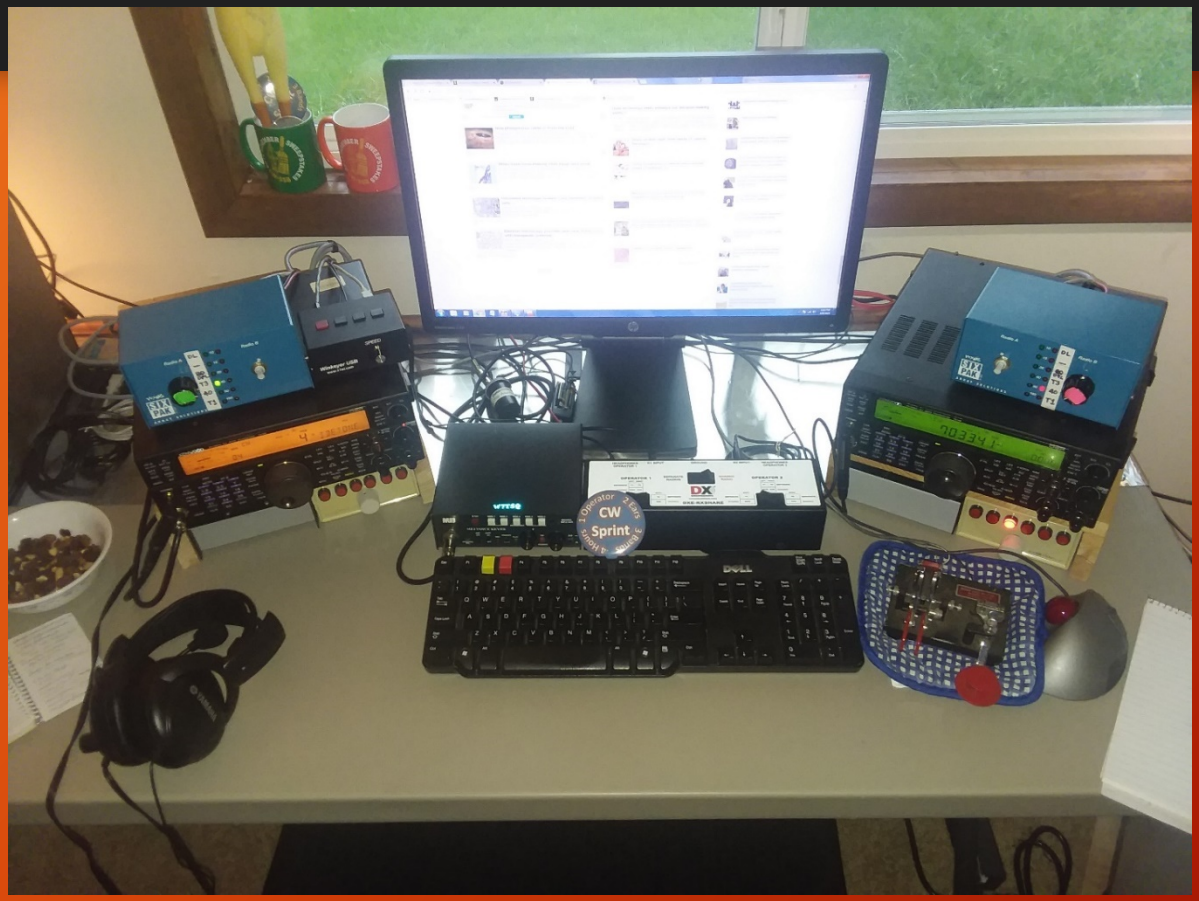


RF Management

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



RF Management



Ground System

- All currents flow on all wires
- 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
- Perimeter ground helps keep lightning outside

The Mobile Station

- RF issues can be more intense
- Special power wiring considerations
- Bonding and the vehicle body
- Mounting antennas

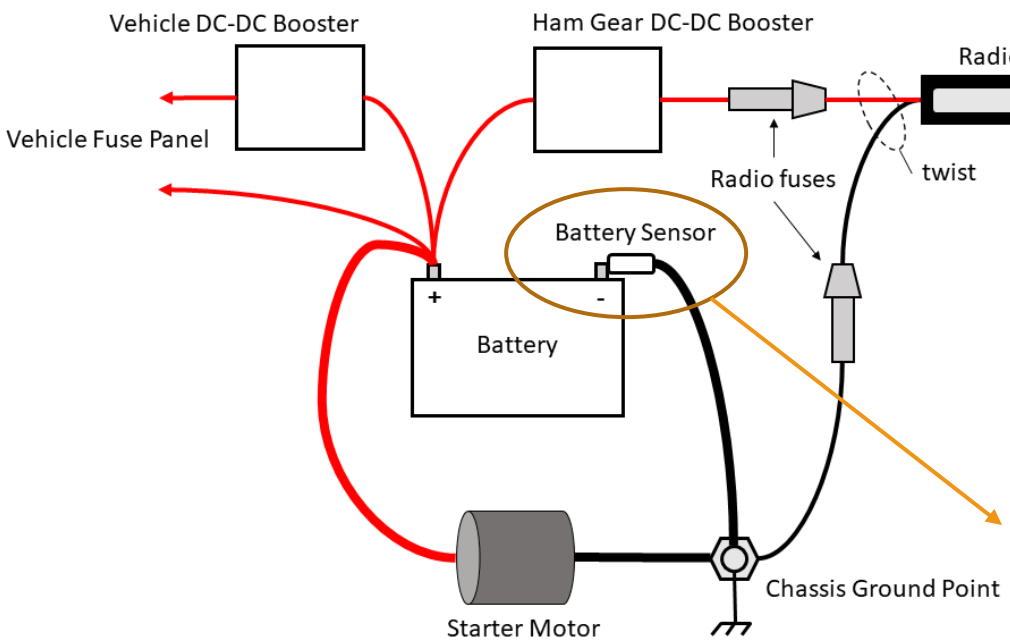
Mobile Power

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

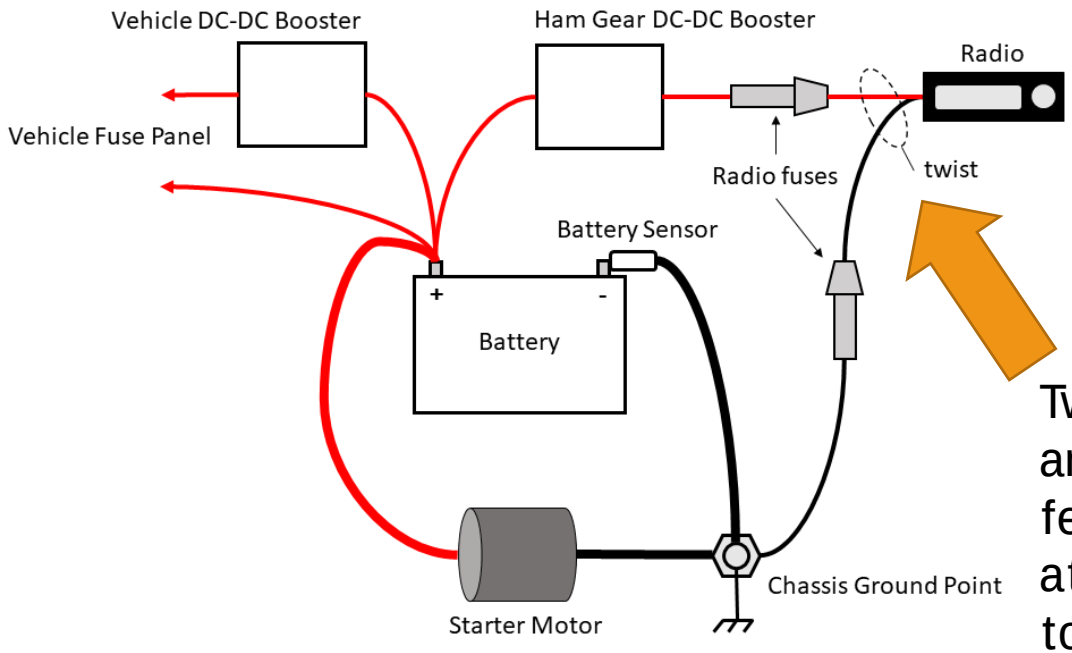
Fusing, Ampacity, Voltage Drop

- 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

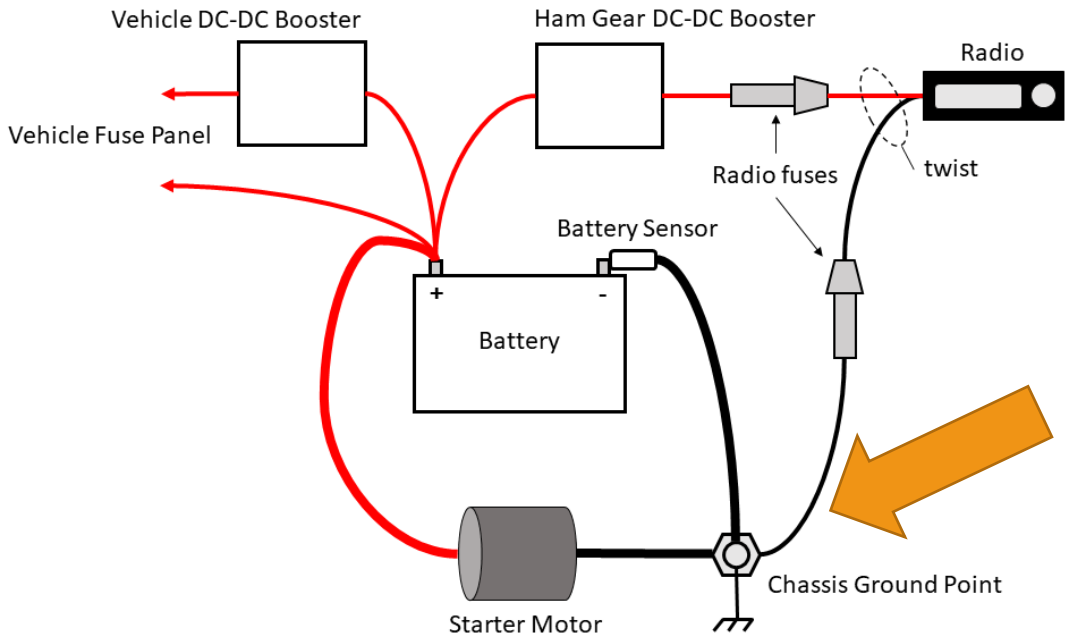


Power Return Connection



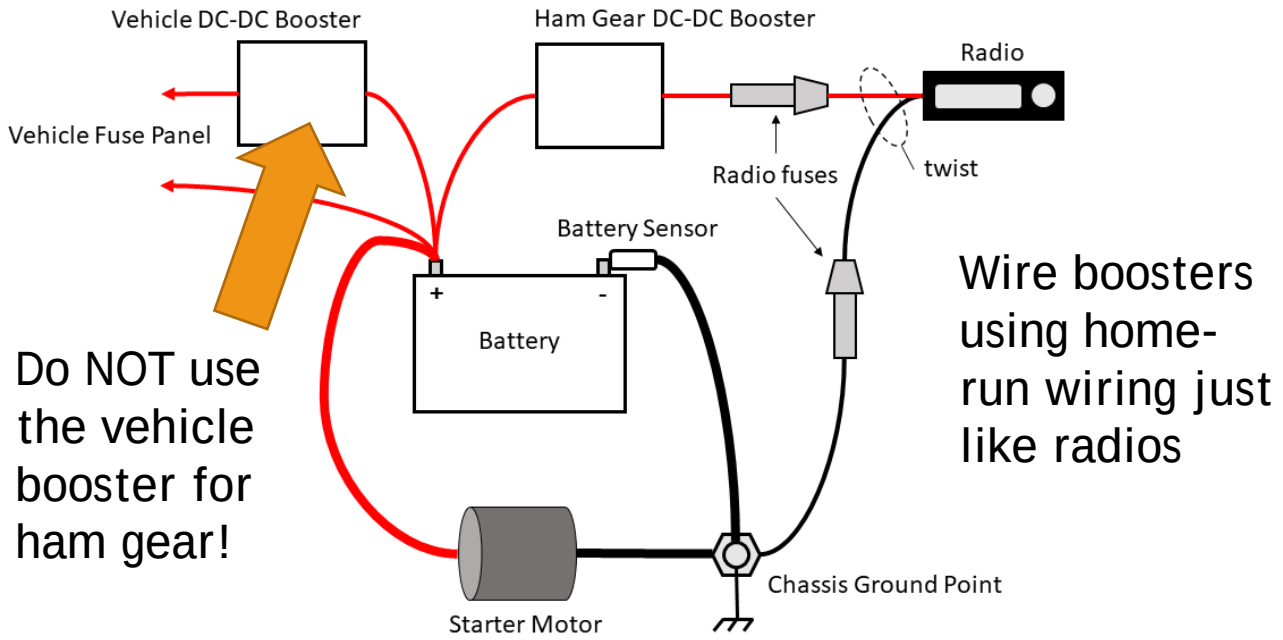
Twist wires and put ferrite cores at the radio to reduce RF pickup

Power Return Connection



Connect dc return here "home-run wiring"

Power Return Connection



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

Mounting Equipment

- Single pieces of gear don't need bonding
- Body panel is part of the antenna system
- Consider 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!

Mounting Antennas

- Bond to body *AT* the antenna
  - Through-panel NMO probably the best
  - Lip mounts need additional body bond
  - Beware of paint!
- Mag-mounts don't work well at HF
  - Insufficient body coupling
  - 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

The Mobile Station

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

ARE WE DONE YET?

THANKS!!

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**