DX Engineering Presents

Grounding & Bonding

Tim Duffy K3LR

With credit to Ward, N0AX

• CTU •
CONTEST UNIVERSITY

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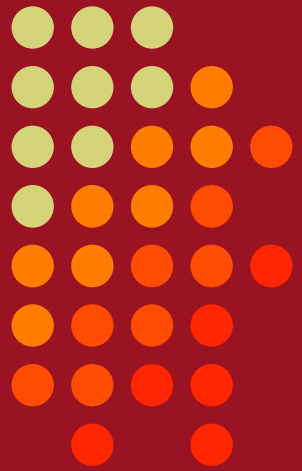
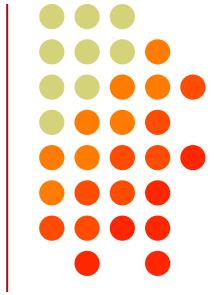
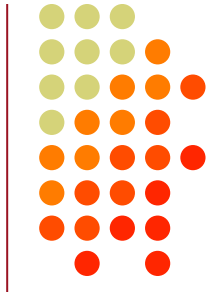


Goals of the Session



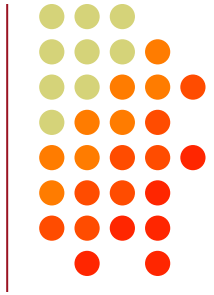
- Understand “ground” and “bond”
- Appreciate the different requirements for ac safety, lightning protection, RF and audio
- Illustrate some techniques
- Show how a system approach works
- Point you at more comprehensive resources

Who Is This Talk For?



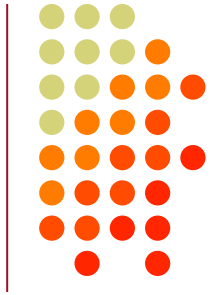
- Station builders…
  - Just starting out
  - Putting up a first tower
  - Expanding a station
  - In lightning country
  - Trying for better performance

Background References



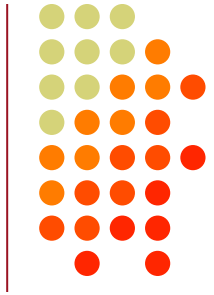
- *ARRL Handbook, ARRL Antenna Book*
- *Grounding and Bonding for the Radio Amateur*
- *NEC Handbook* – at your library
- *Standards and Guidelines for Communication Sites* (Motorola R56) – available online
- *Lightning Protection for the Amateur Station* (Ron Block, NR2B – Jun/Jul/Aug 2002 QST) – ARRL website
- *Power, Grounding, Bonding, and Audio for Amateur Radio* and *RFI, Ferrites, and Common Mode Chokes For Hams* – available at **k9yc.com/publish.htm**

What *IS* "Ground" Anyway



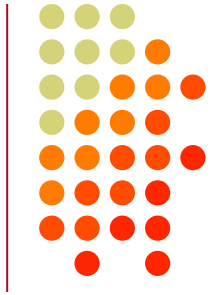
- The right answer depends on what you are trying to do
- What you are trying to do depends on frequency, voltage, current
- Your **safety** depends on the right answer
- Your **equipment** depends on the right answer

What *IS* "Ground" Anyway



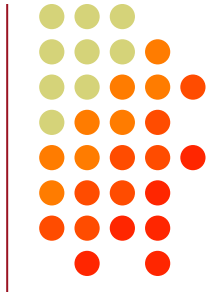
- The right answer depends on what you are trying to do
- What you are trying to do depends on frequency, voltage, current
- Your **safety** depends on the right answer
- Your **equipment** depends on the right answer
- Your **sanity** depends on the right answer

What *IS* "Ground" Anyway



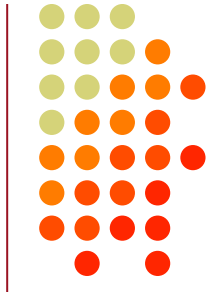
- It can be a noun, verb, and adjective – *all at the same time*
- Noun - an "earth connection" (ac, lightning) or a local reference potential (circuits, RF)
- Verb - an action "to connect to the reference potential"
- Adjective - a type of connection, such as a "ground conductor" or "ground system"

What *IS* "Ground" Anyway



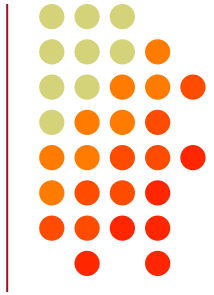
- Fuzzy definitions:
  - "RF ground" – ain't no such thing
  - "Ground loops" – not the problem you think it is
  - "Single-point ground" – it depends…
- The Earth is NOT – a magic sink into which we can pour RF or lightning and expect it to magically and safely disappear

What *IS* "Bonding" Anyway



- A connection intended to keep two points at the same voltage
- Sounds expensive but it's not
- Sounds hard but it's not
- Requires the right connecting materials and hardware
- Works in your favor for ac safety, lightning protection, and RF management

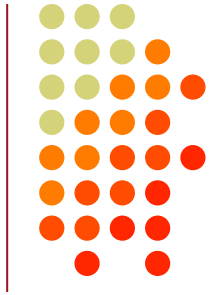
What *IS* "Bonding" Anyway



- 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

- Inside the ham station, use…
  - Strap (20 ga) or heavy wire (#14 or larger)
  - Flat-weave braid – Tinned Copper Braid - wide
    - Braid from old coax deteriorates

AC Safety Grounding

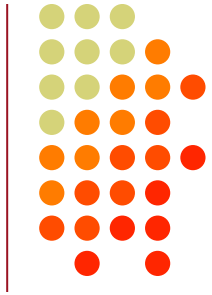


- Before we go any further…

SAFETY FIRST

- Don't be the one to say, "I didn't think it would happen to me…"

AC Safety Grounding



- And a friendly reminder from your AHJ*

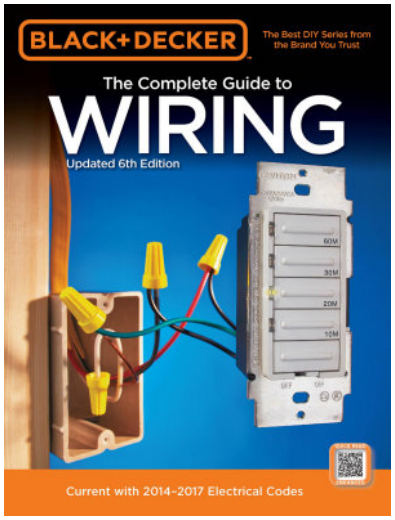
LOCAL CODE IS THE LAW

- If you don't have a local code, use the NEC

* - Authority Having Jurisdiction

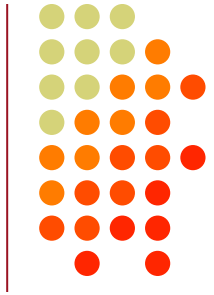
AC Safety Grounding

- If you aren't sure you know what you're doing…get a how-to reference



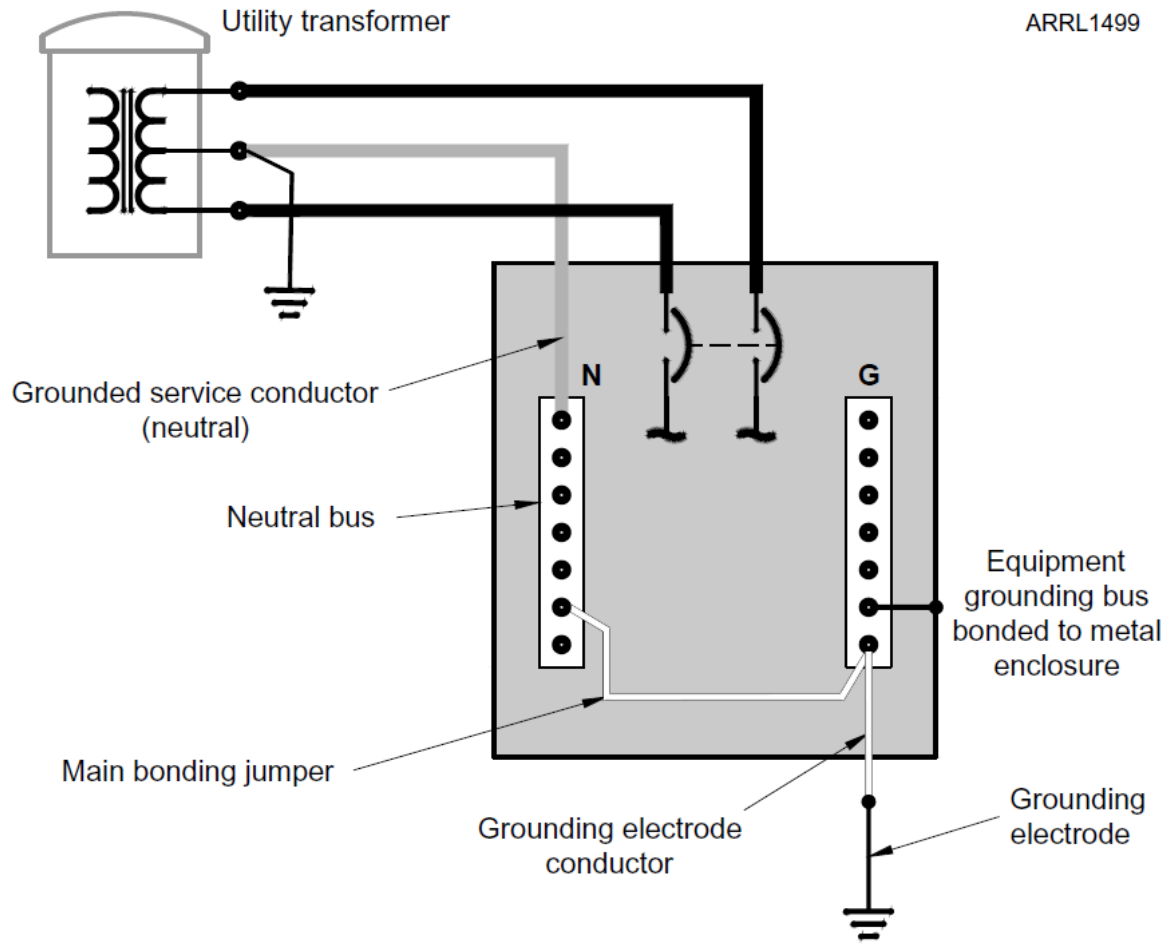
- Or hire a professional electrician

AC Safety Grounding

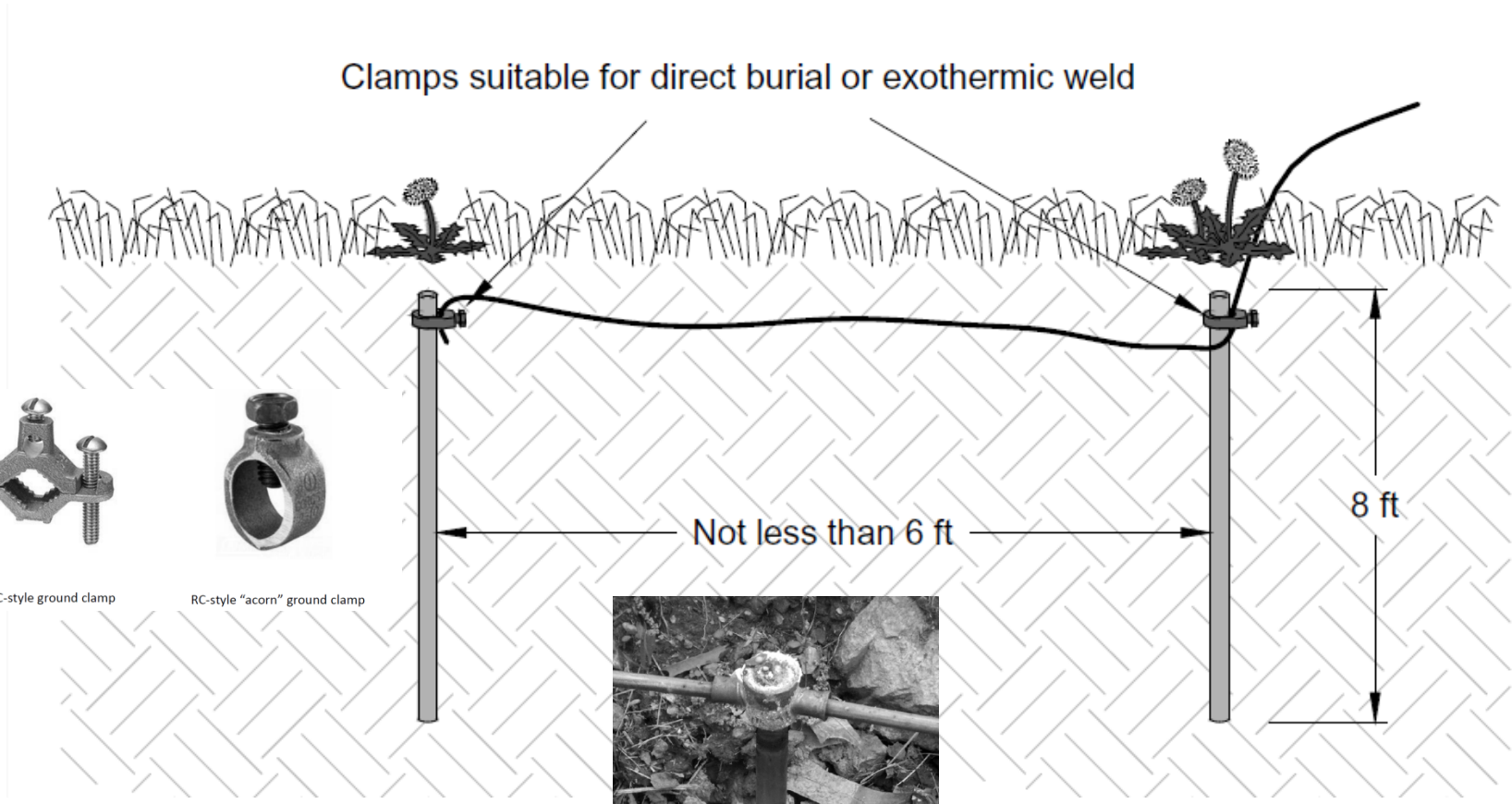


- Grounding for ac safety has several names
  - “Equipment ground”, “third-wire ground”, “green-wire ground”
- Purpose is two-fold
  - Provides a path to ac common point for fault current (shorts, leakage)
  - Stabilizes the ac power voltage during faults or transients, such as lightning

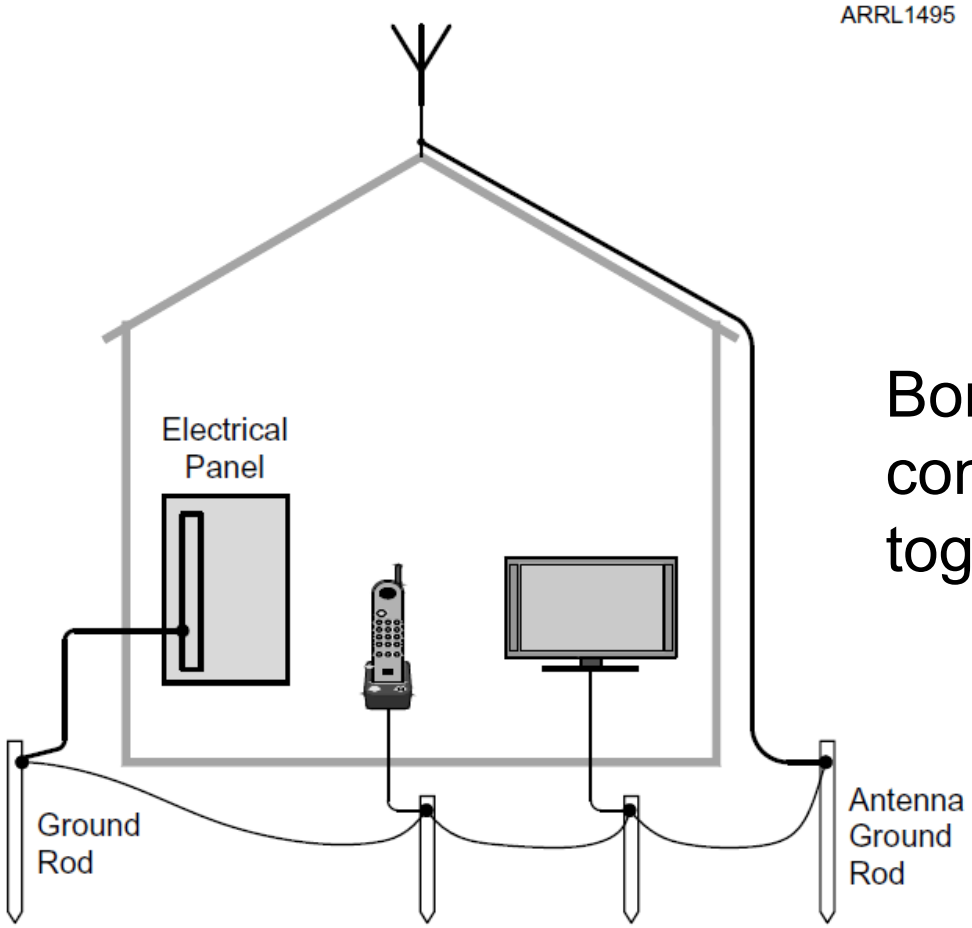
AC Safety Grounding



AC Safety Grounding

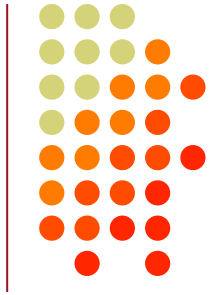


AC Safety Grounding



Bond ALL earth connections together

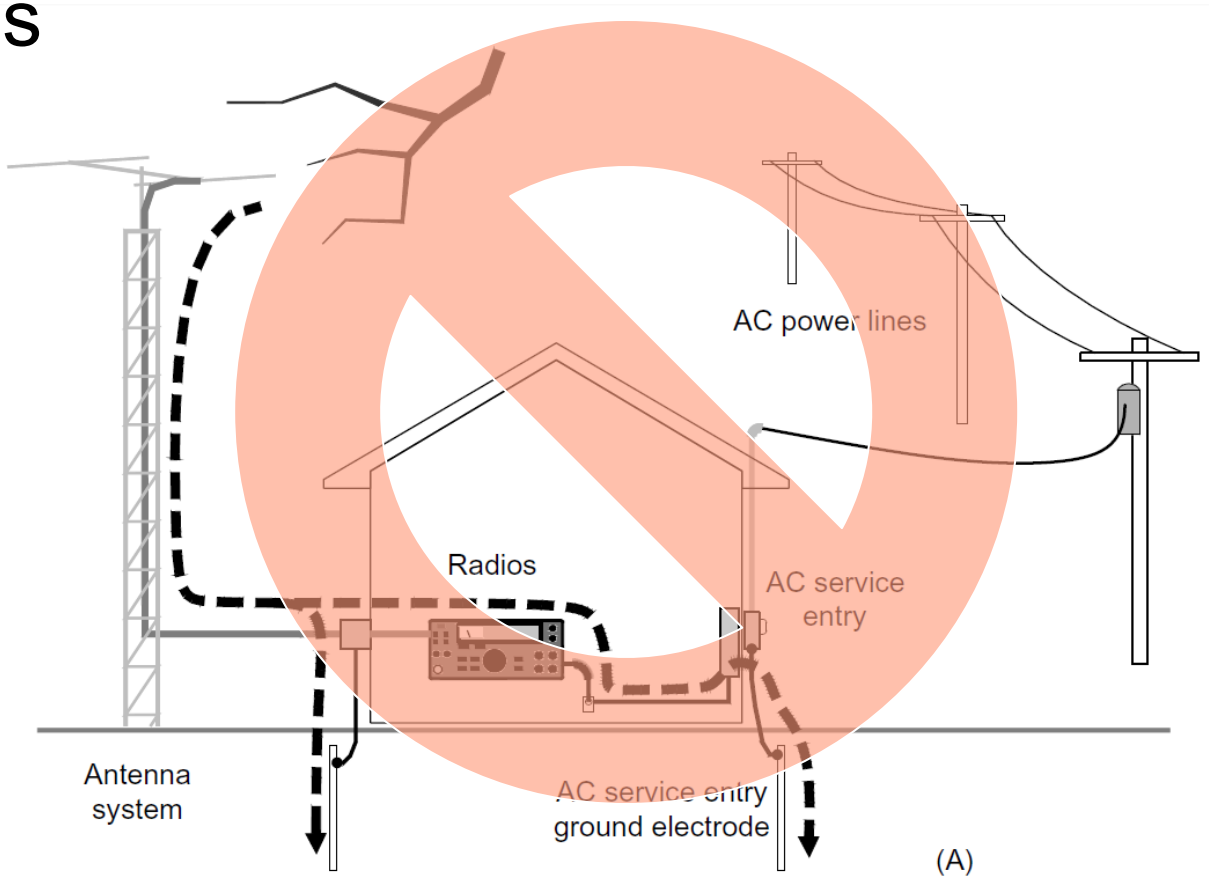
Lightning Protection



- You can't steer lightning, but…you *can* help lightning make "good decisions"
  - Heavy, low-impedance paths to the Earth
  - 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

- Ground paths should go *around* your station



Lightning Protection

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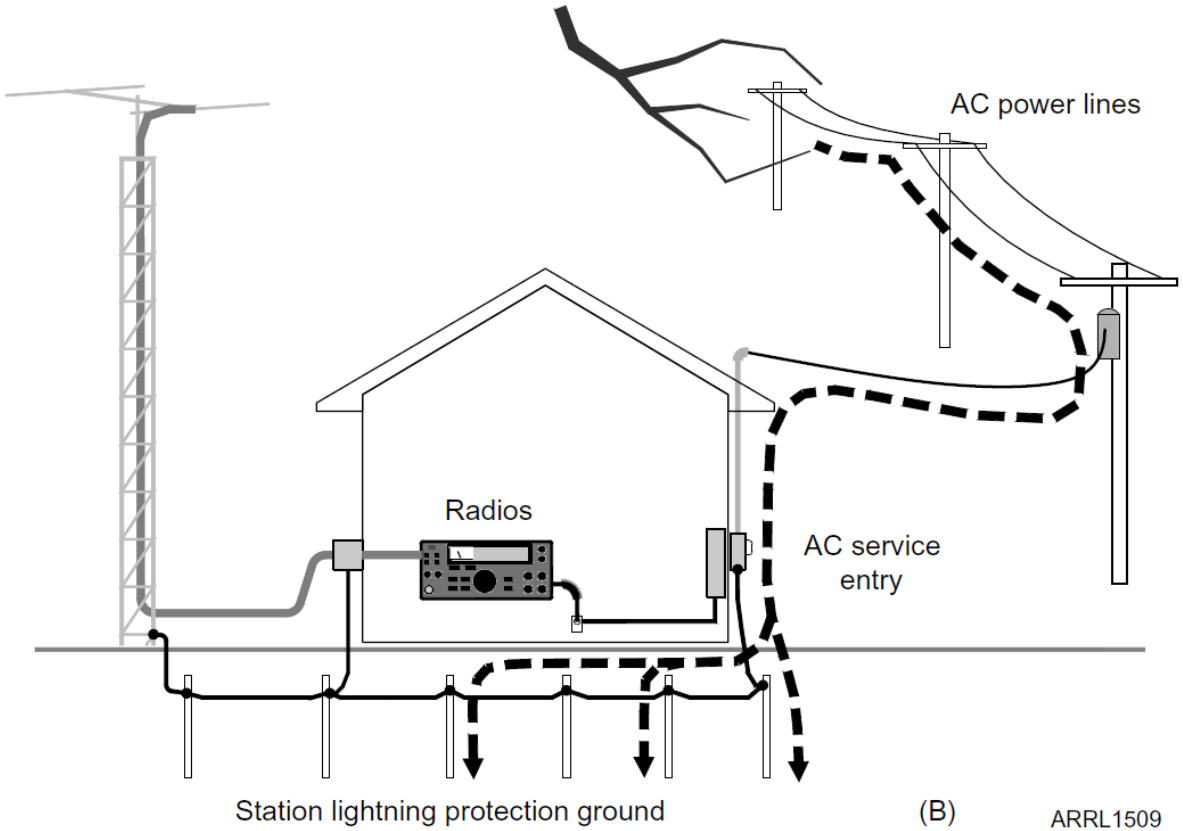
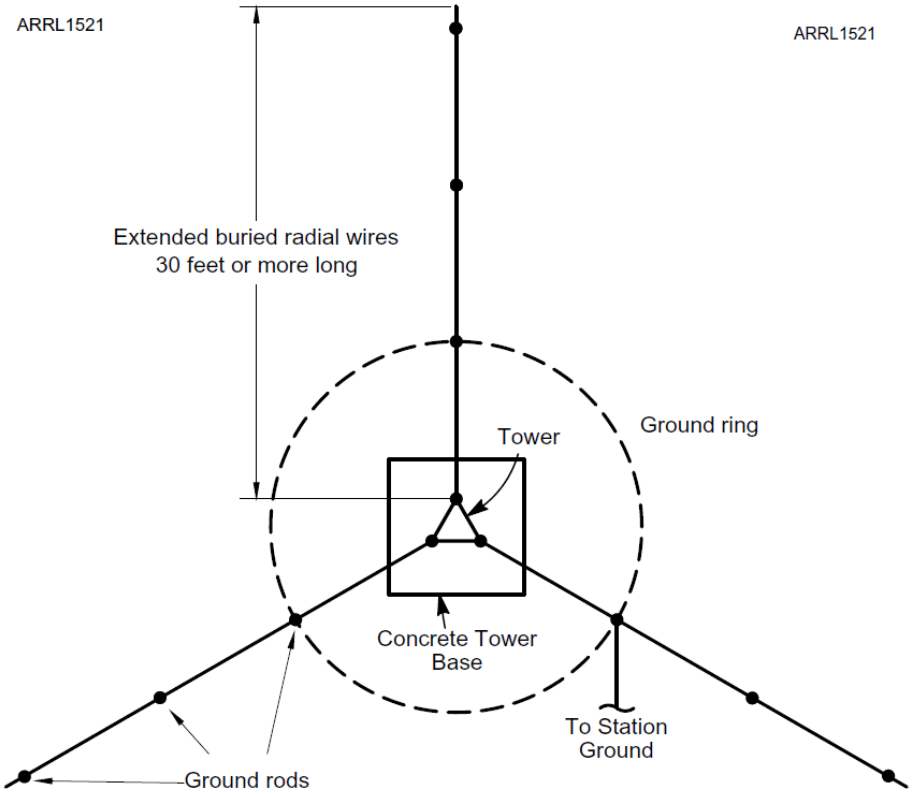


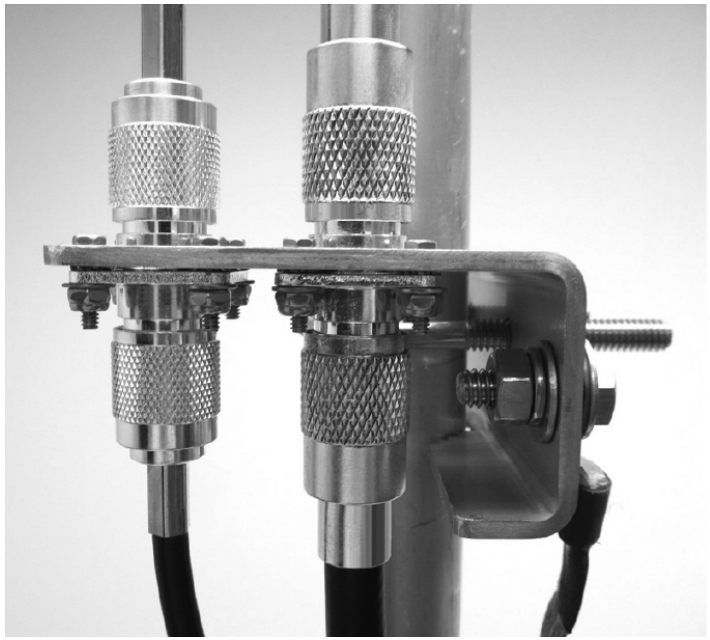
Lightning Protection

- Tower grounding



Lightning Protection

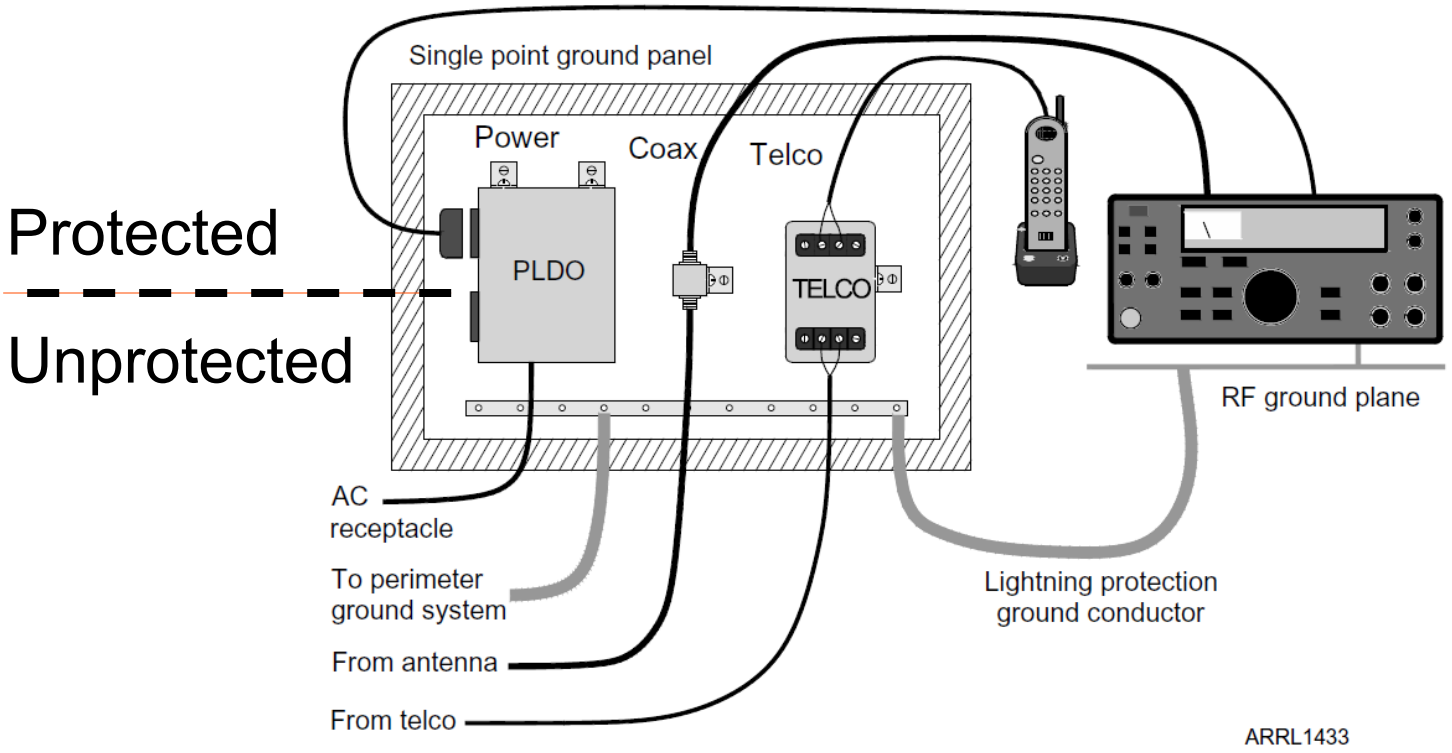
- Bond feed lines to the tower



- Spark gaps across insulators

Lightning Protection

- Single-point Ground Panel



Lightning Protection

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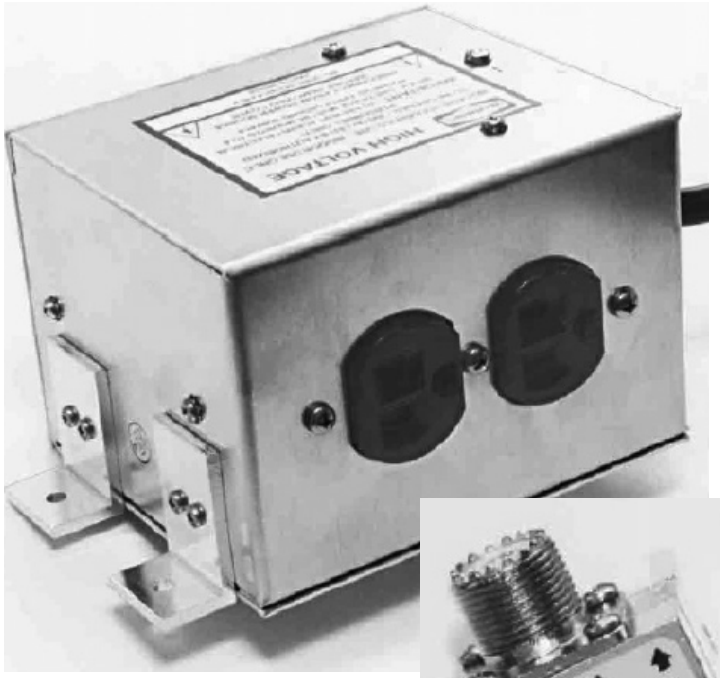

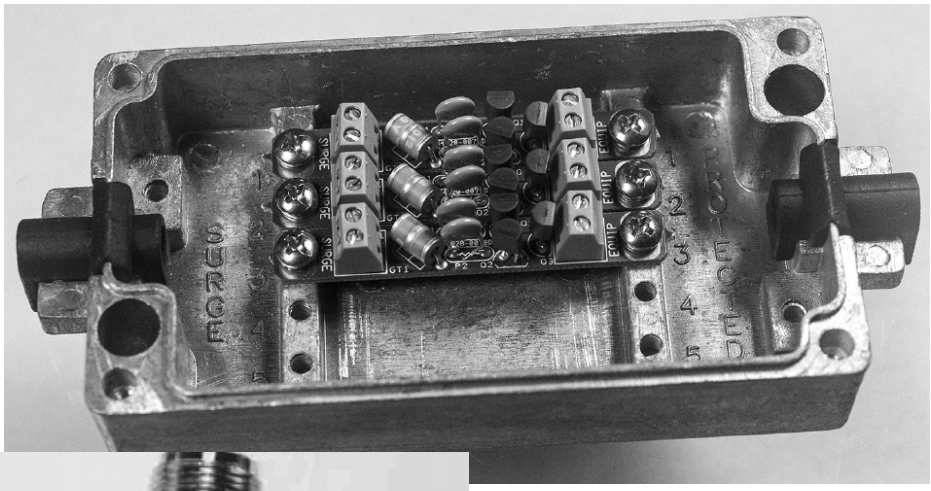

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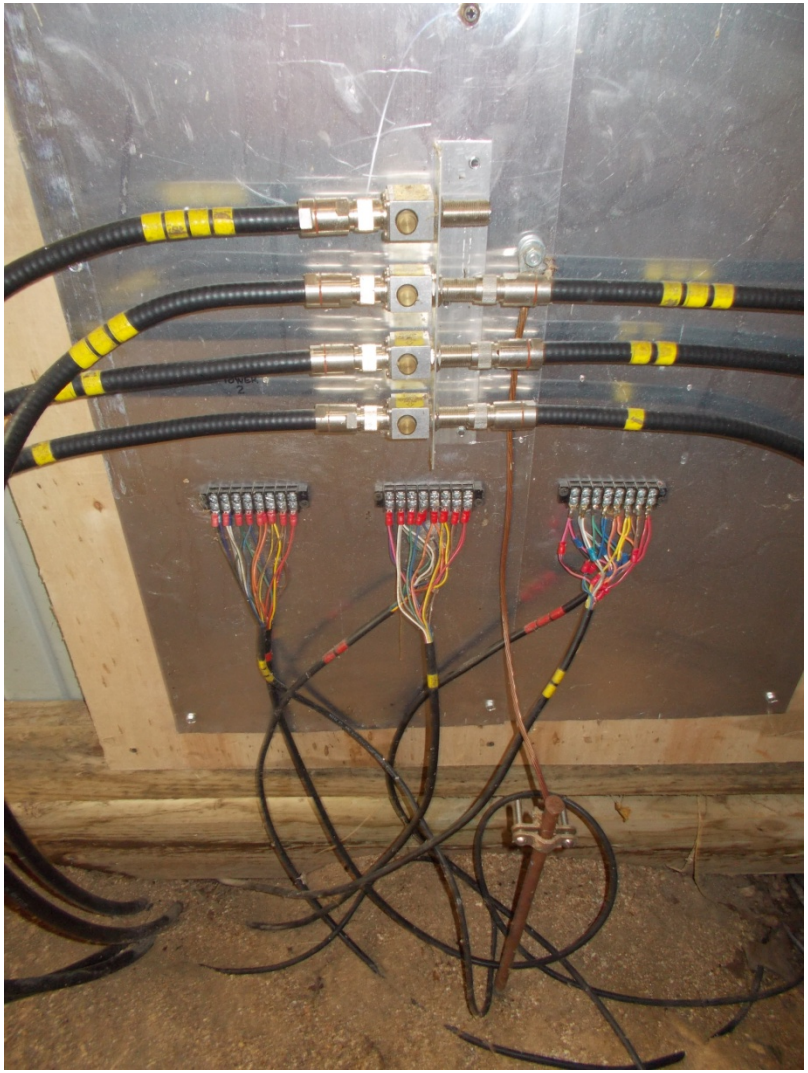
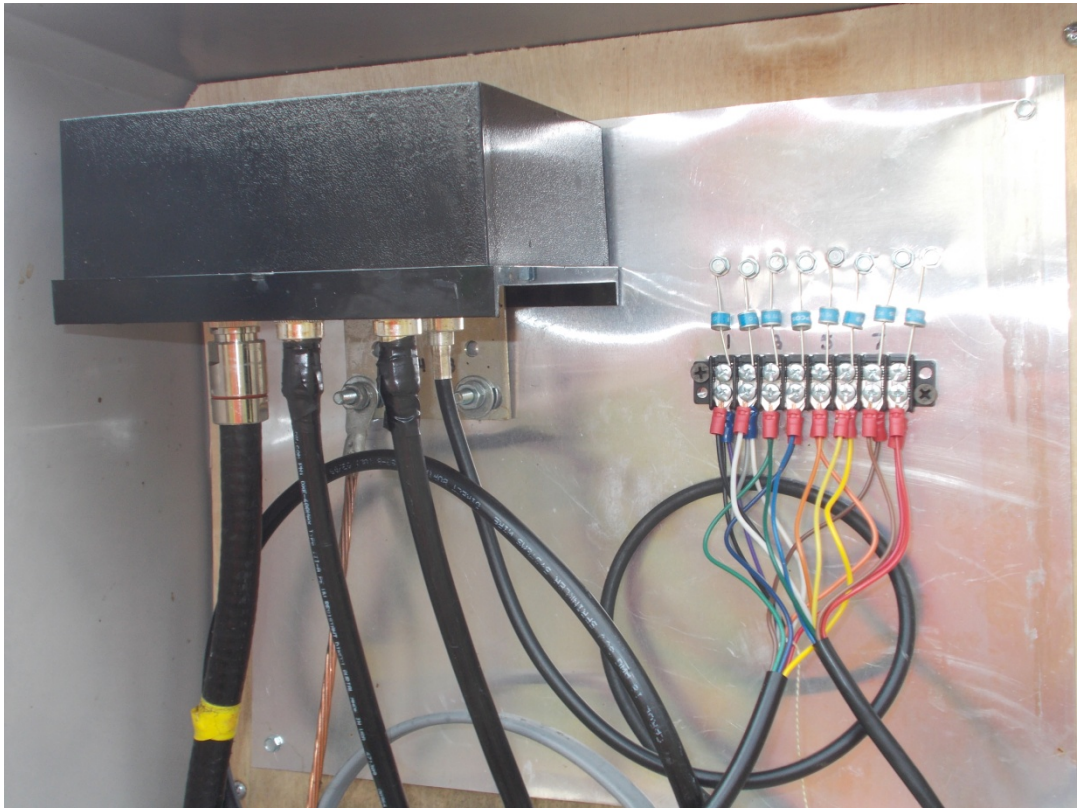
Lightning Protection

- Single-point Ground Panel



Lightning Protection

- Single-point Ground Panel

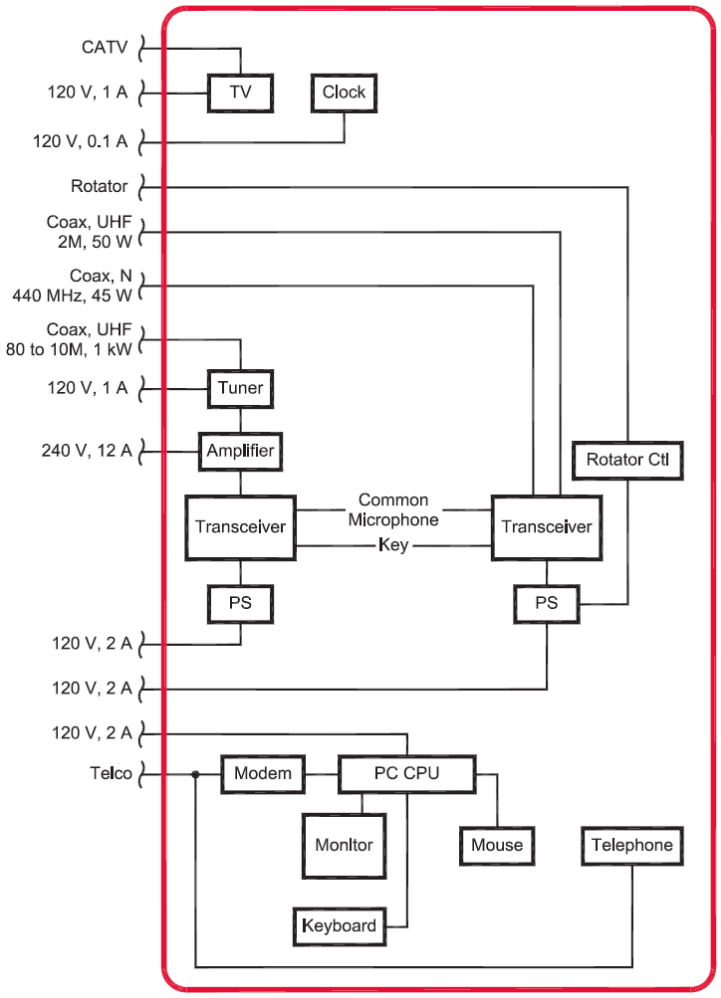


Lightning Protection

- Single-point Ground Panel

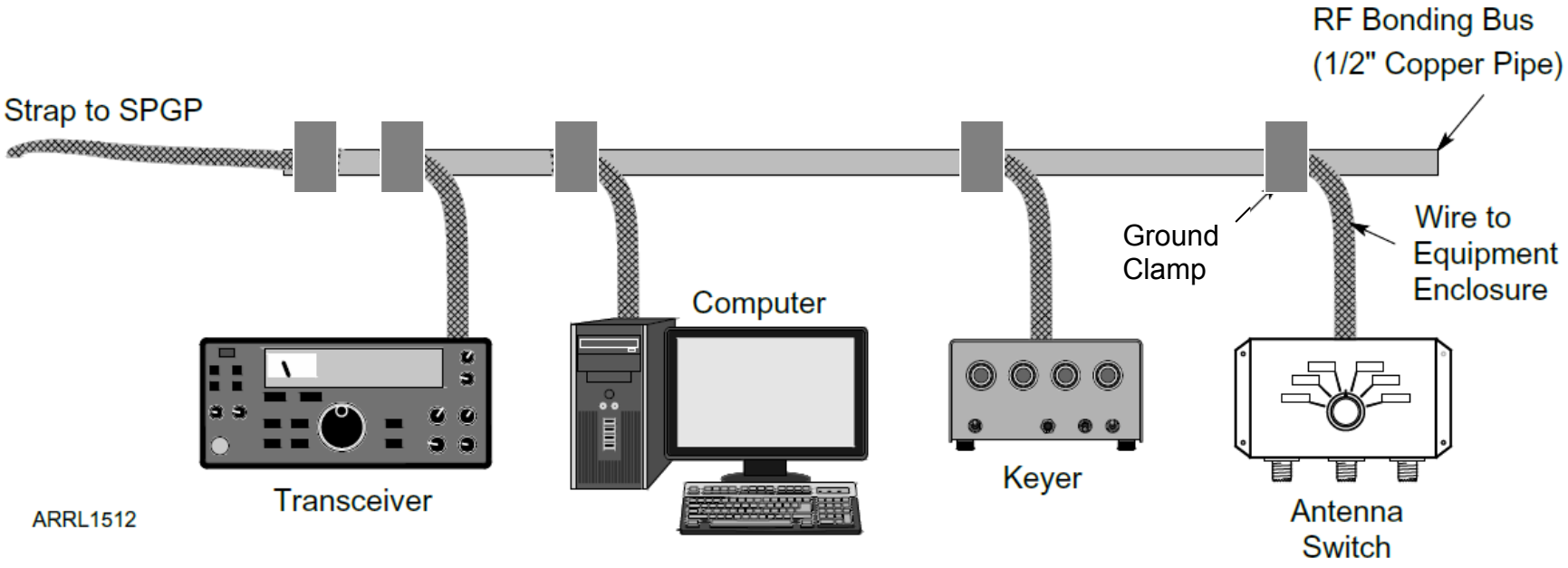
Lightning Protection

- Protected Zones
  - Every line crossing the boundary must be protected
  - Must all have a common or bonded ground connection
  - Bond equipment within the station

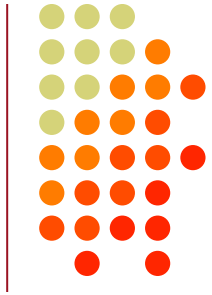


Lightning Protection

- Bonding inside the shack



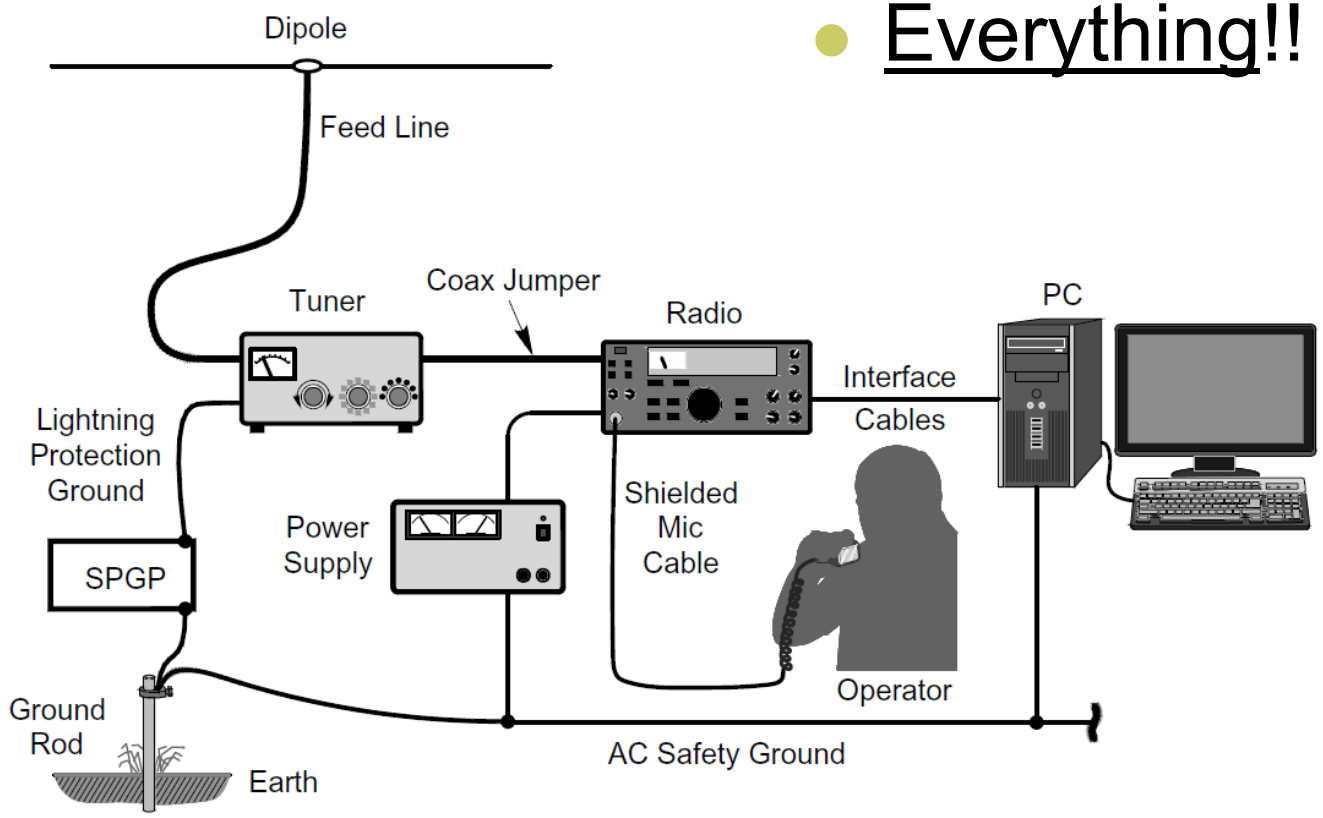
RF Management



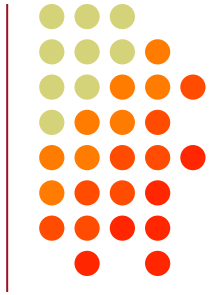
- Everything in the station is an antenna

RF Management

- Everything!!



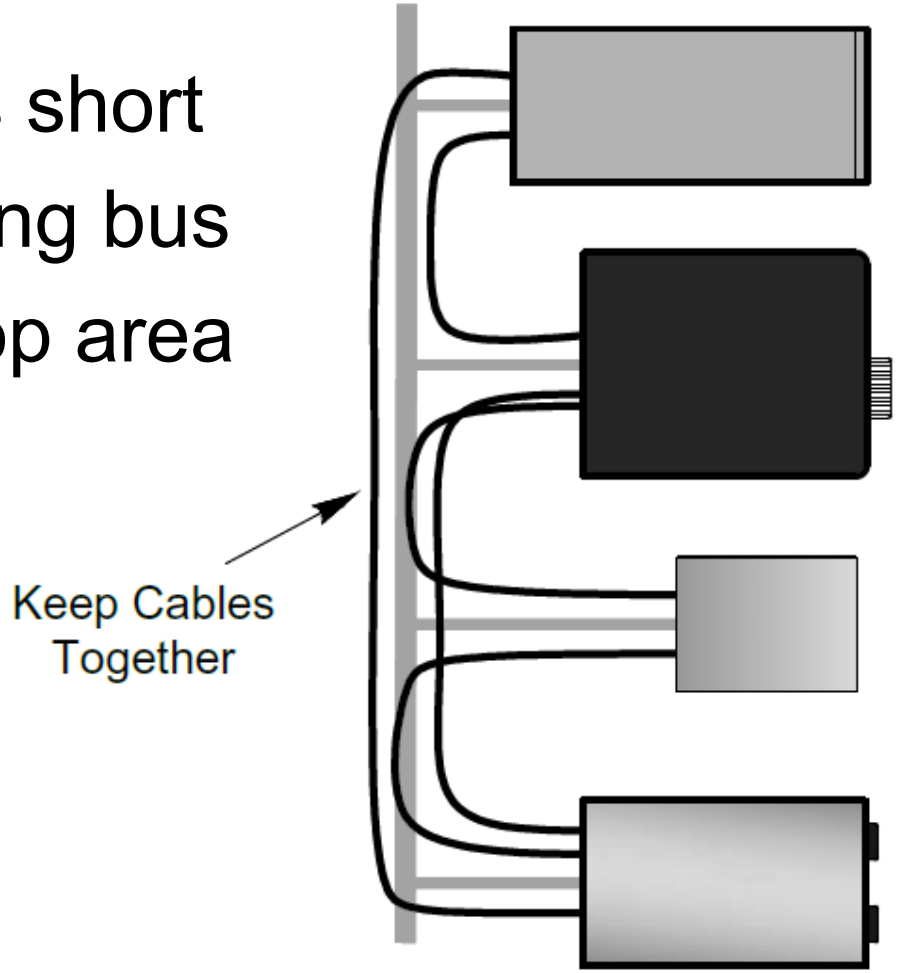
RF Management



- Everything in the station is an antenna
- Forget about an “RF ground”
- Concentrate instead on bonding
- Equalize voltage to minimize current
  - Eliminates “hot spots”
  - Reduces RFI from common-mode current
  - Reduces sensitivity to physical configuration
  - Minimizes audio “buzz” and hum

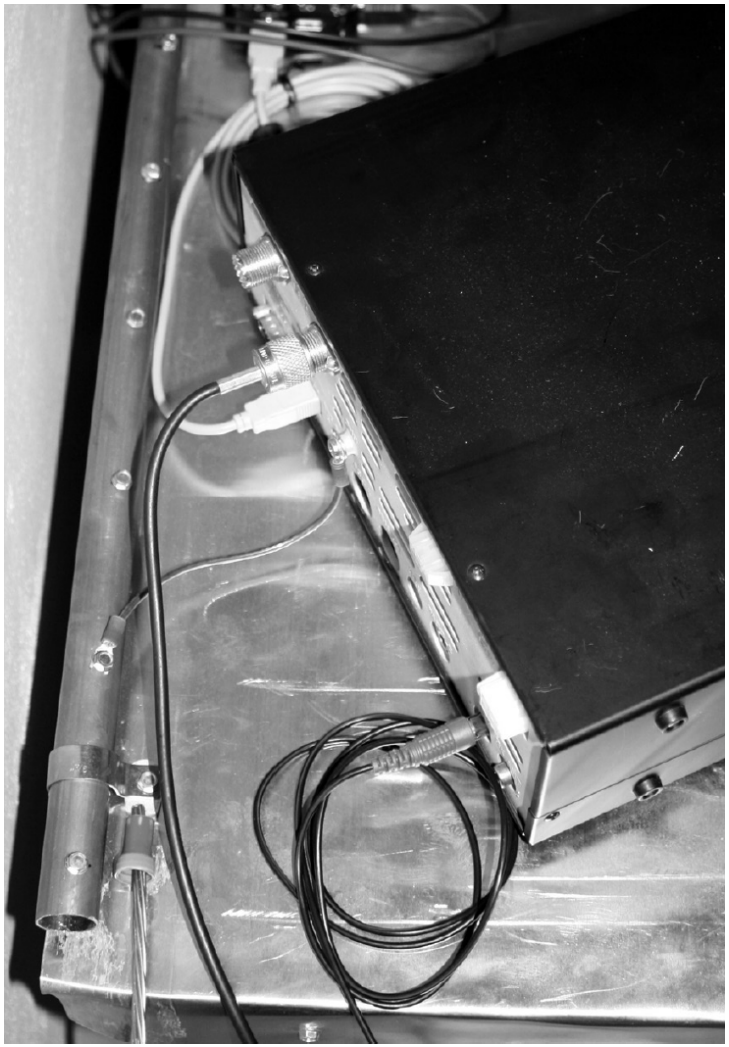
RF Management

- Keep cables short
- Use a bonding bus
- Minimize loop area

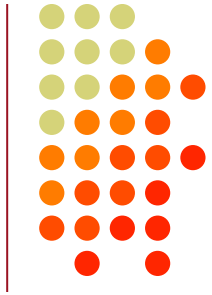


RF Management

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

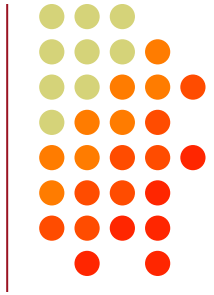


Ground System



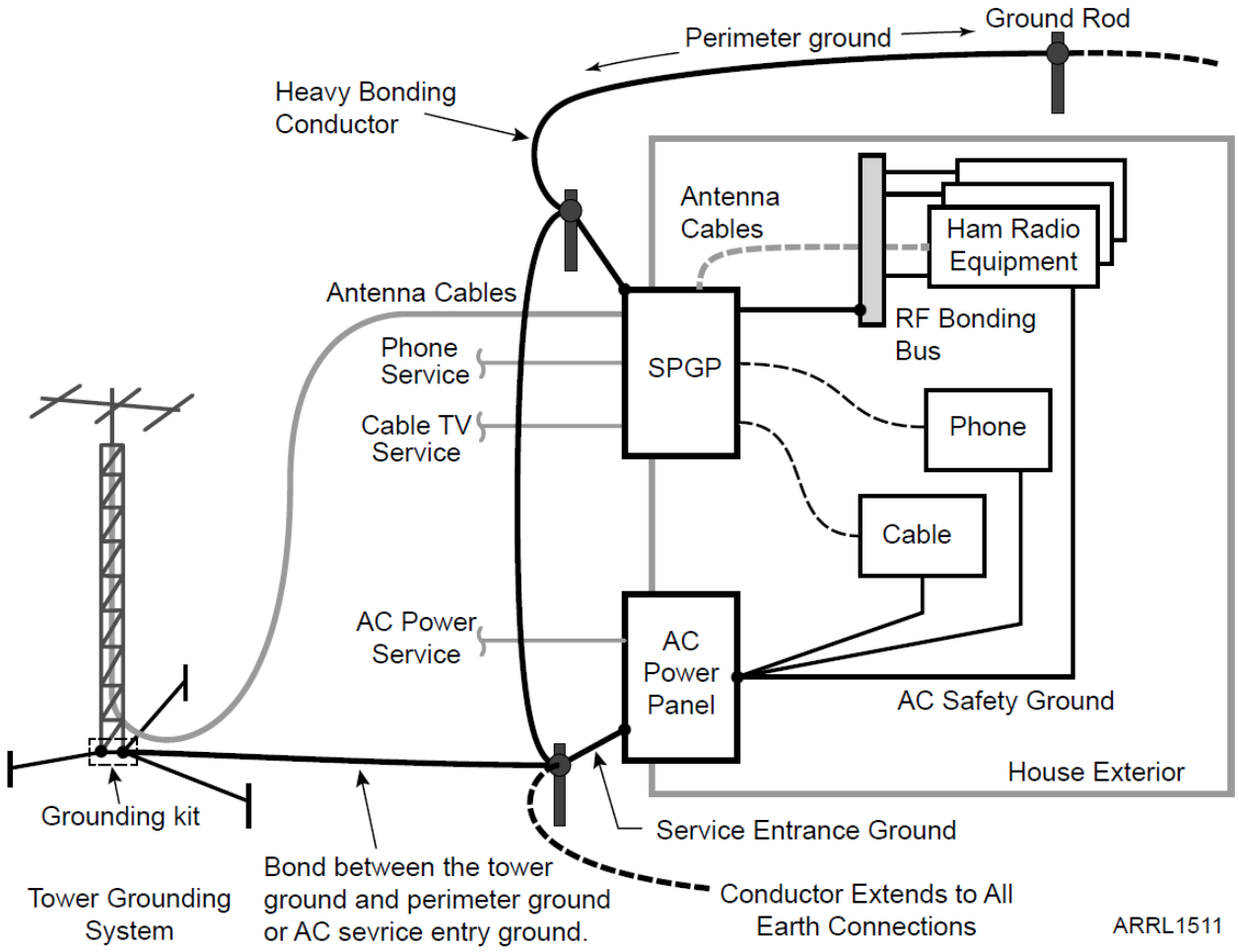
- Now for some good news…

Ground System

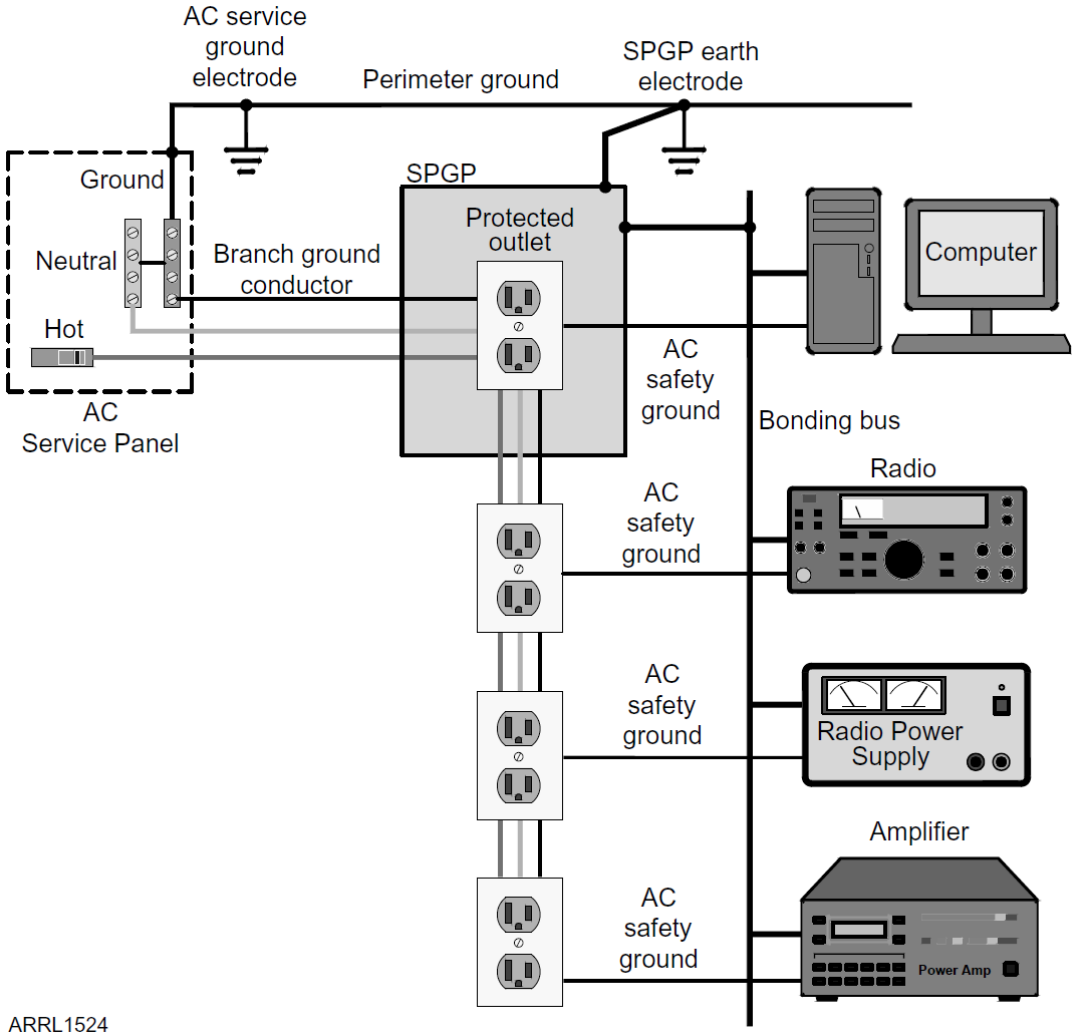


- “One system to rule them all”
- All currents flow on all wires
- A single, solid ground system made of short, heavy, direct connections satisfies all of the requirements for…
  - AC Safety
  - Lightning Protection
  - RF Management & Clean Audio

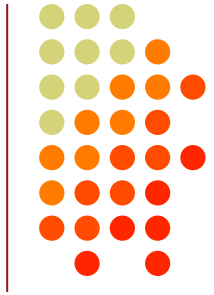
Ground System



Ground System

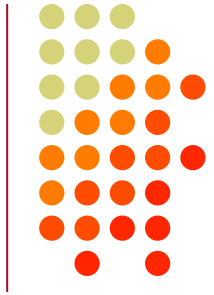


Additional Resources



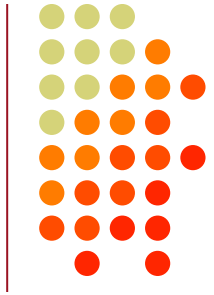
- Professional Associations and Companies
  - National Fire Protection Association (**www.nfpa.org**)
  - International Association of Electrical Inspectors (**www.iaei.org**)
  - Mike Holt Enterprises (**www.mikeholt.com**) — training and continuing education for electricians, many tutorials
  - Polyphaser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

Additional Resources



- Standards
  - 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**
  - W8JI’s web pages on ground systems (**w8ji.com/ground_systems.htm**)