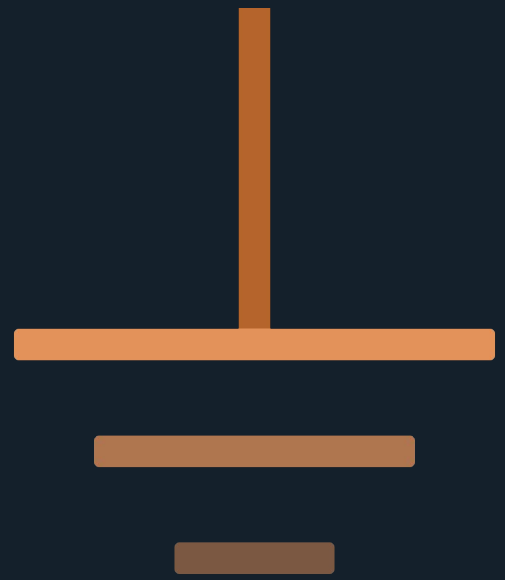
KLAMATH BASIN AMATEUR RADIO ASSOCIATION

Grounding & Bonding

for the amateur radio station



Station bonding · Arrestors · Towers · Ground loops · Ground audit

Charles J Boening · K7AKT

Terms: grounding and the code

Grounding · a connection to earth, giving fault and surge current a path

Bonding · connecting metal parts together so they stay at the same voltage

Equipotential · everything at the same voltage, even while a surge passes

Ground potential rise · the jump in earth voltage around a ground rod during a strike

Ground rod · usually 8 ft, ⅝ in copper-clad; the code calls it a "grounding electrode"

Ufer ground · rebar in a concrete footing or tower base, bonded in as a ground

AHJ · authority having jurisdiction: your electrical inspector

EGC · equipment grounding conductor: the green or bare wire, the outlet's third prong

GEC · grounding electrode conductor: service panel to the ground rod

IBT · intersystem bonding termination: the lug at the service for bonding other systems

GFCI · ground-fault circuit interrupter: trips on leakage current to protect people

AWG · American Wire Gauge: smaller number, bigger wire (6 AWG is heavier than 10)

Listed · tested and certified (by UL or similar) for that specific use

NEC · NFPA 780 · R56 · electrical code · lightning-protection standard · Motorola site standard

Ref: ARRL, Grounding and Bonding for the Radio Amateur; NEC Articles 100, 250, 810

SPEAKING THE SAME LANGUAGE · 2 OF 2

Terms: hardware and RF

SPGP · single-point ground panel: the one bonded entry for every cable

SPD · surge protective device, for power or signal lines

UL 1449 · the safety standard a real surge protector should meet

GDT · gas discharge tube: a sealed spark gap, the usual coax arrestor element

MOV · metal-oxide varistor: clamps surges on power and control lines

Exothermic weld · a molded, fused copper joint; Cadweld is one brand

Common-mode current · current on the outside of a shield, or on all wires together

Choke / 1:1 balun · a device that blocks common-mode current

Ground loop · two or more paths between grounds that form a current loop

λ (lambda) · wavelength; λ/4 is a quarter wavelength

VF · velocity factor: how much slower RF travels in coax than in free space

CAT · computer-aided transceiver: computer control of the radio

Ref: ARRL, Grounding and Bonding for the Radio Amateur; K9YC

THE BASICS

Three jobs, one connected system

AC safety

NEC Article 250

Gives fault current a low-impedance path back to the panel so the breaker trips. The green wire in your outlets does this job.

Lightning & surge

NEC Article 810 · NFPA 780

Steers surge energy to earth outside the house and keeps every conductor at the same potential while it happens.

RF management

Bonding + chokes

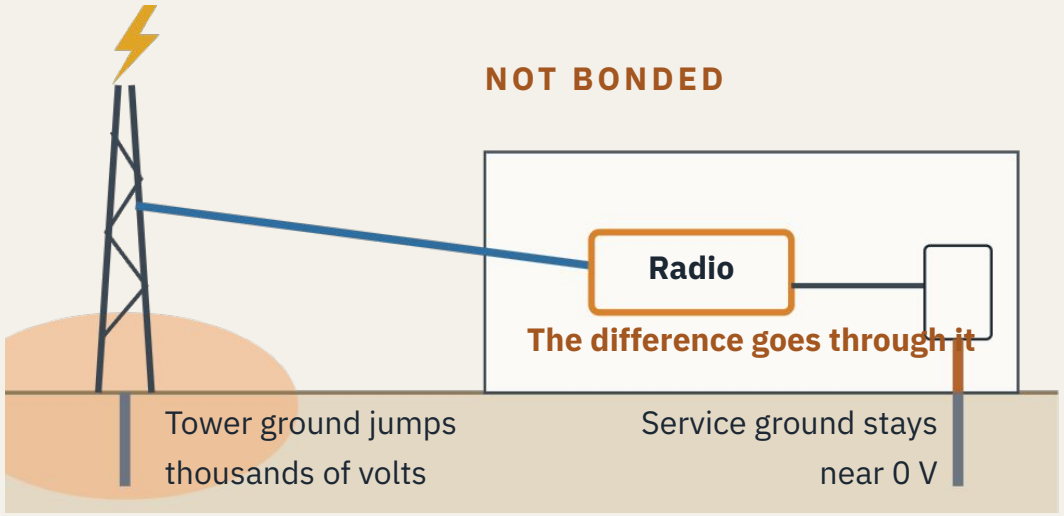
Keeps RF on the antenna and out of your mic, keyboard and the neighbor’s TV by controlling common-mode current.

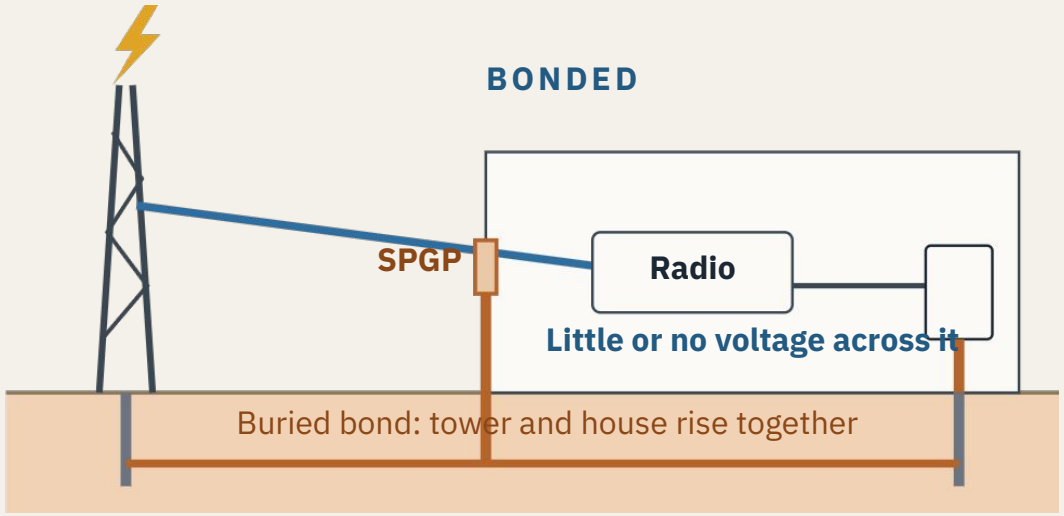
> **The common thread is bonding:** tie everything together so it all rises and falls together. “Ground” is the reference; bonding is what protects you.

Ref: ARRL, Grounding and Bonding for the Radio Amateur; NEC 250, 810; NFPA 780

WHY BONDING MATTERS

Same potential, no current through your gear





Lightning: earth near a strike rises thousands of volts. Unbonded grounds put that difference across your gear.

AC faults: an unbonded chassis can sit at 120 V until someone touches it and something grounded.

People: a hand on the radio and the other on a pipe or metal desk puts you in the path.

Ref: ARRL, Grounding and Bonding for the Radio Amateur; NFPA 780

WHY WIRE SIZE ISN’T THE WHOLE STORY

Inductance, not resistance, rules

~10,000 V

across just one meter of “ground” wire during a strike

Resistance opposes *steady* current (DC, 60 Hz). A fatter wire fixes it.

Inductance opposes *changing* current. Only shorter, straighter and wider help.

Strike: ~10 kA/µs × ~1 µH per meter = ~10,000 V per meter (V = L × di/dt)

Short and straight
Every extra foot adds voltage. No coiled excess.

Wide strap beats round wire
More surface, less inductance. Keep length under 5× width.

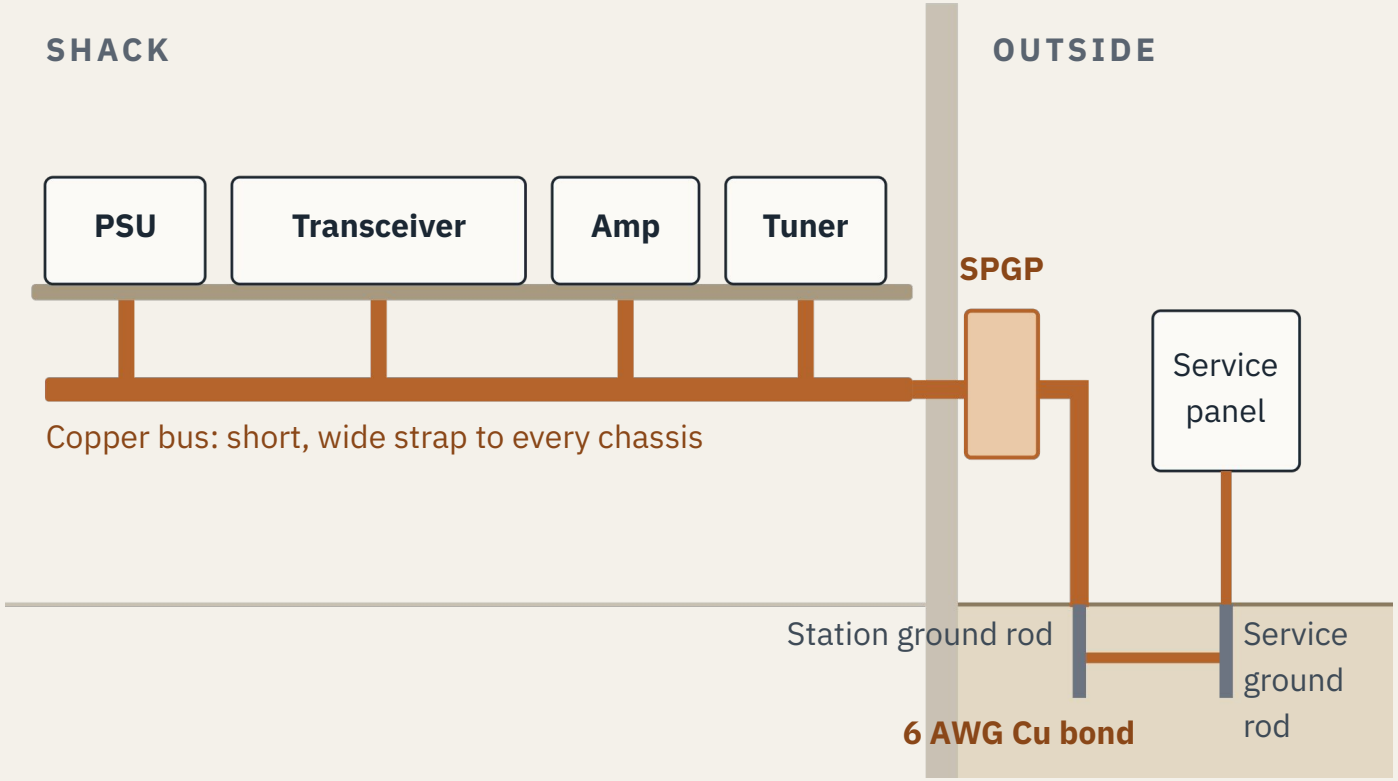
Gentle bends
Sharp corners invite side flashes. Aim for 8 in or larger radius.

At RF, long ground leads are antennas
λ/4 on 20 m is about 17 ft: an upstairs “RF ground” can resonate.

Ref: ARRL, Grounding and Bonding for the Radio Amateur; Motorola R56

STATION GROUNDING

Bond every chassis to one bus



- One copper bus (bar, pipe or 1.5–2 in strap) behind the desk. Everything bonds to it.
- Each chassis gets its own ½–1 in strap, under 5× its width long. Don’t daisy-chain.
- The bus then runs to the SPGP and the station ground rod.
- The station ground rod **must** be bonded to the service ground rod. No isolated “radio ground.”

Ref: ARRL, Grounding and Bonding for the Radio Amateur; NEC 810.21(J)

THE OUTLET'S THIRD PRONG

Keep the outlet ground, but don't rely on it

Do: it's your AC safety ground

- It trips the breaker if a hot wire faults to a chassis.
- Always use 3-prong cords. Never a cheater plug or a cut-off ground pin.
- Your gear is already tied to it through every power cord, so the station bus will be too.

Don't: use it as your lightning ground

- Not a code connection point: 810.21(F) sends the arrestor ground to the IBT or the grounding system at the service.
- 12–14 AWG wire, often 50 ft or more through walls: far too much inductance for a surge.
- At RF it's just another long wire.

The fix is a bond, not the outlet: 6 AWG or larger copper from the station ground rod to the service ground rod or IBT (810.21(J)).

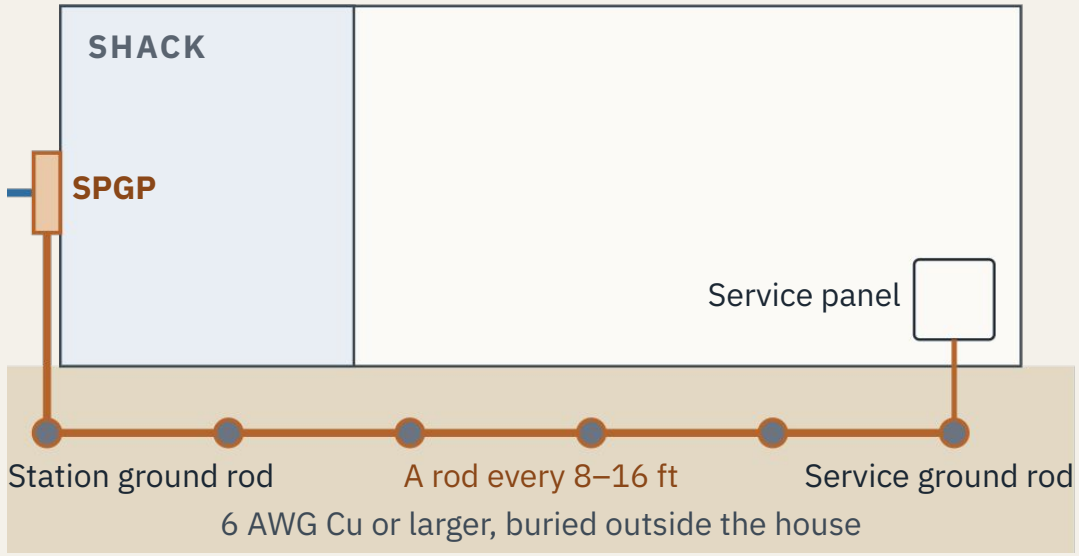
Shack far from the service? Two layouts on the next slide. Keep using the shack's outlets, through a surge strip bonded to the station ground (slide 10).

Ref: NEC 250.94, 810.21(F) and (J); ARRL, Grounding and Bonding for the Radio Amateur

SHACK FAR FROM THE SERVICE?

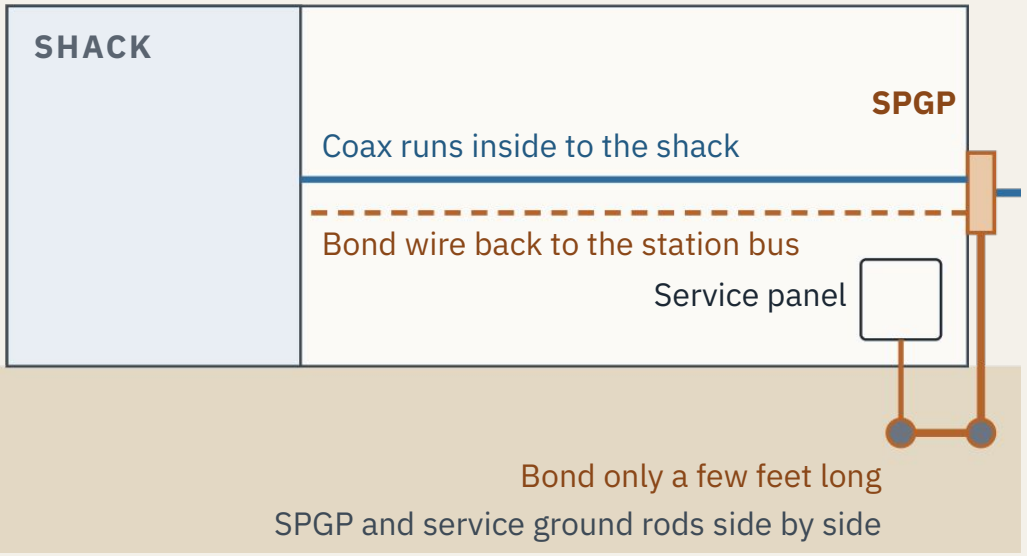
Two ways to bond to the service ground

1 · Bond in a trench with extra ground rods



Trench: works anywhere; extra rods help with lightning. At every rod: an exothermic weld (e.g. Cadweld) or a clamp listed for direct burial. **Never solder.**

2 · Move the cable entry near the service

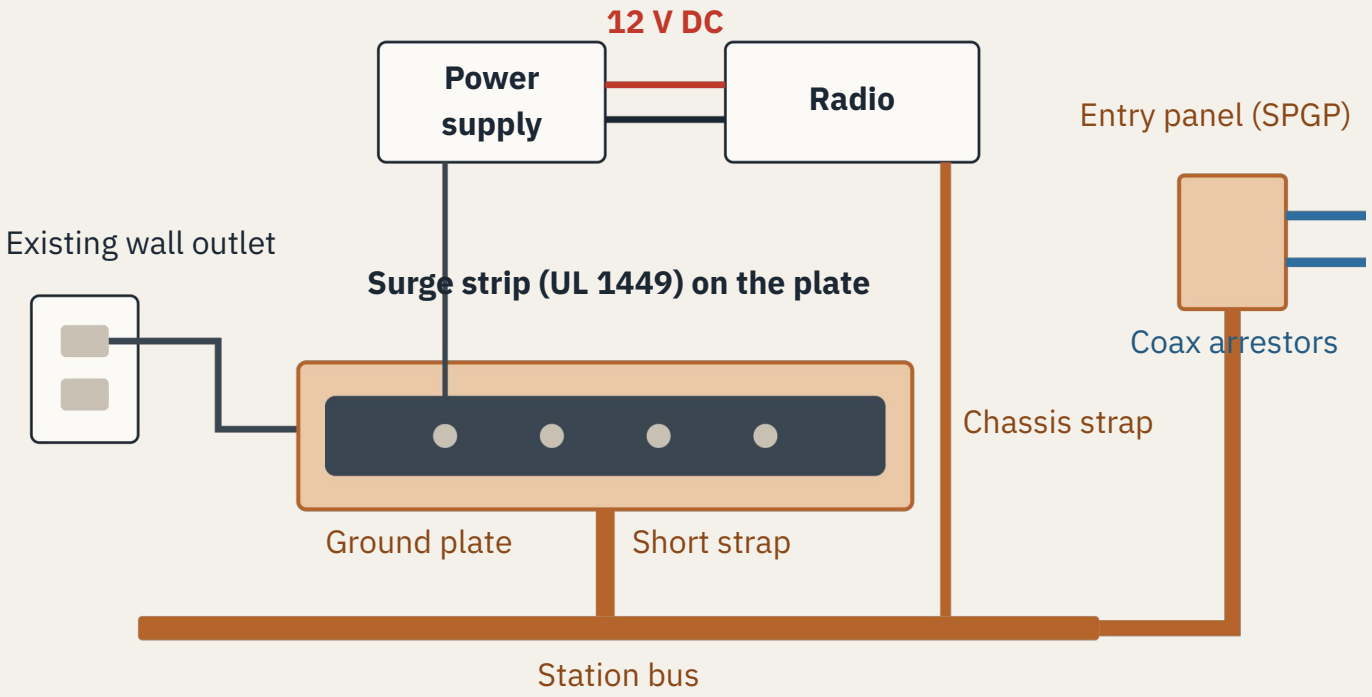


Moved entry: the shortest bond, so the coax ground and the house AC ground stay closest in voltage. Tradeoff: longer coax indoors.

Ref: NEC 810.21(J); ARRL, Grounding and Bonding for the Radio Amateur

STATION AC

Same outlet, one protected strip



Keep using the shack's outlet. Nothing gets rewired.

Mount a quality surge strip on a ground plate, strapped to the station bus.

Plug the power supply and other station gear into that strip only.

Why: the AC protector and the coax arrestors now share one ground reference.

Ref: ARRL, Grounding and Bonding for the Radio Amateur (protected outlet strips on the SPGP)

OLDER HOMES

Only 2-prong outlets? Your options

Best

Have an electrician run a new grounded circuit to the shack.
Or add a separate ground wire from the outlet back to the panel or grounding system (NEC 250.130(C)).

Stopgap

A GFCI outlet may replace a 2-prong outlet (NEC 406.4(D)). It protects people from shock.
But it’s labeled “No equipment ground”: the third pin goes nowhere, so surge strips can’t work.

Never

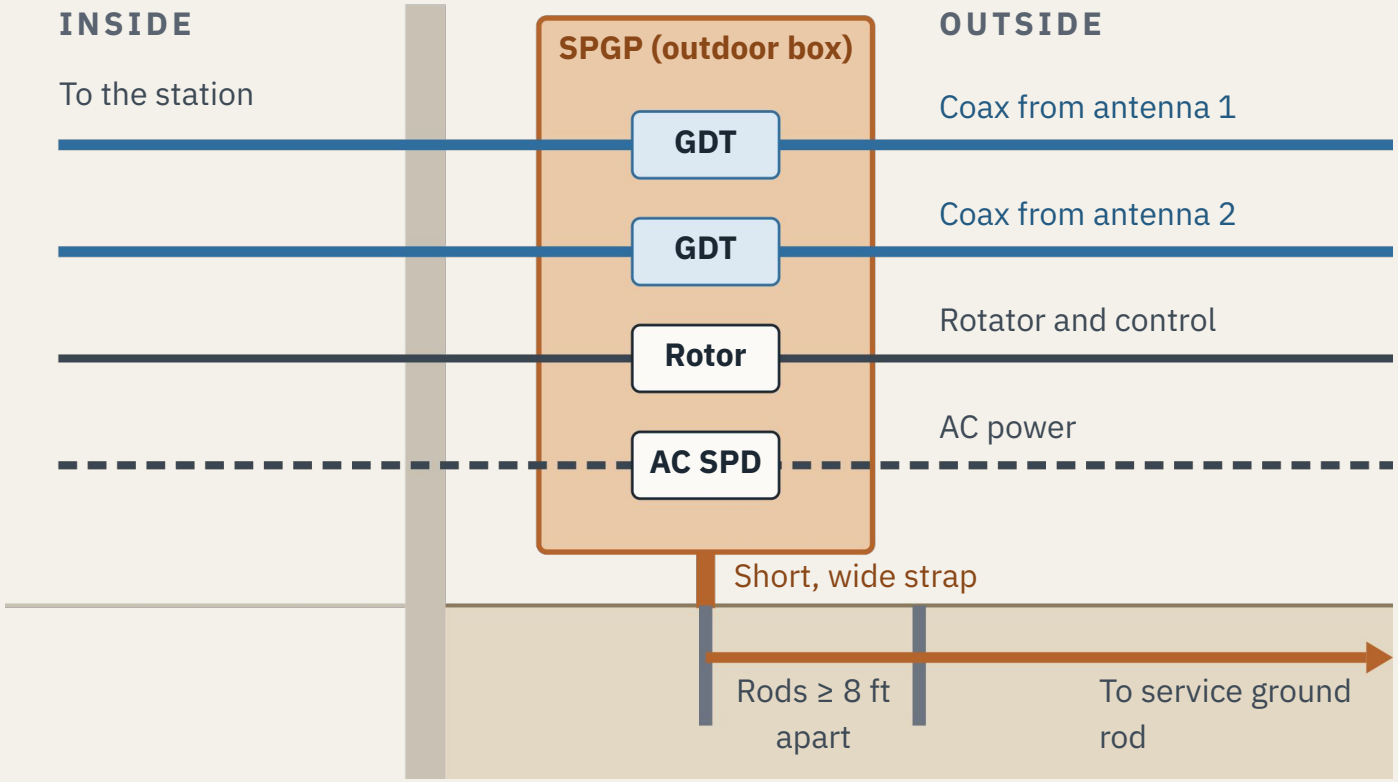
Cheater adapters, or a 3-prong outlet with nothing on its ground screw.
A “bootleg” jumper from neutral to ground: it can put 120 V on every grounded chassis.

> **Your station bus and ground rod don’t replace the equipment ground.** They handle surges and RF; the breaker still needs a fault path. Test first: some older metal-clad wiring is grounded.

Ref: NEC 250.130(C), 406.4(D); ARRL, Grounding and Bonding for the Radio Amateur

ENTRY POINT

One way in: the single-point ground panel



- Mount the panel **outside**, or right where cables enter, so surges stop before they get in.
- Coax, rotator, control, power and Ethernet all enter at **one** place.
- Protectors bolt directly to the panel: bare metal, no paint.
- Short 1.5–3 in strap to the ground rod; rods bonded to the service ground rod.

Ref: ARRL, Grounding and Bonding for the Radio Amateur; NR2B, QST 2002; NEC 810.57

A MEMBER'S STATION

From the desk to the ground rod



1 · Station bus

Copper pipe on bronze clamps, with a braid strap from each chassis.



2 · Bus to the entry

A strap leaves the end of the bus for the window feedthrough.



3 · MFJ-4601 window panel

Coax passes through; braid bonds the panel's ground lug. Note the clamp-on ferrite.



4 · Outdoor entry box

Copper bus bar with coax arrestors bolted on; one ground conductor runs to the ground rod.

Ref: ARRL, Grounding and Bonding for the Radio Amateur

LIGHTNING ARRESTORS

Pick the right protector for each line

Type	Passes DC?	Best for	Notes
Spark gap	Yes	Open-wire and ladder line	Cheap; fires late and erodes
Gas discharge tube (GDT)	Yes; DC-blocked models don’t	Most HF and VHF coax	Element replaceable on many units
Quarter-wave stub	No; center is grounded	Single-band VHF/UHF lines	Rugged; nothing to wear out
Control-line protector (MOV or GDT)	Yes	Rotator, switch and tower cables	One element per conductor
AC surge protector (SPD)	n/a	Station power	Whole-house unit plus a strip on the station ground

OK: just one of the two

Only disconnecting: no help on the air or if you forget.

Only arrestors: always on, but can’t stop everything.

Best: both

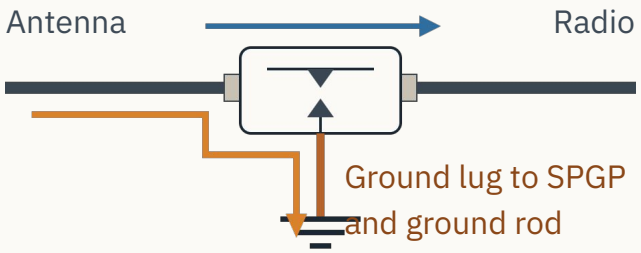
GDT arrestors on a grounded SPGP.

And disconnect for storms and trips.

Ref: ARRL, Grounding and Bonding for the Radio Amateur; NEC 810.57

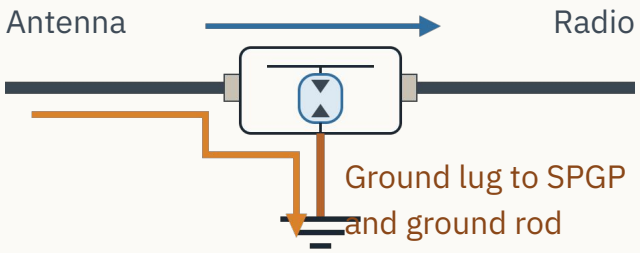
INSIDE THE ARRESTOR

Spark gap, gas tube or shorted stub



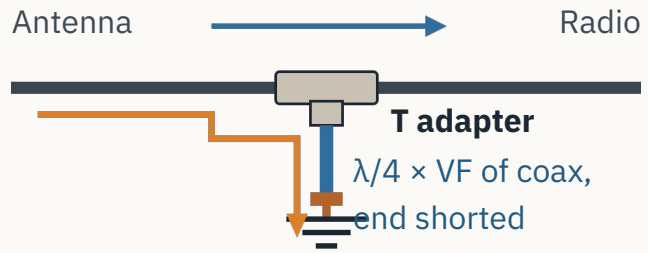
Spark gap

Coax in, coax out, ground lug. Electrodes arc over at several thousand volts. Cheap, any band; fires late and erodes.



Gas discharge tube (GDT)

Same block with a gas-filled tube: fires lower and more consistently. Any band; passes DC; element often replaceable.



Quarter-wave shorted stub

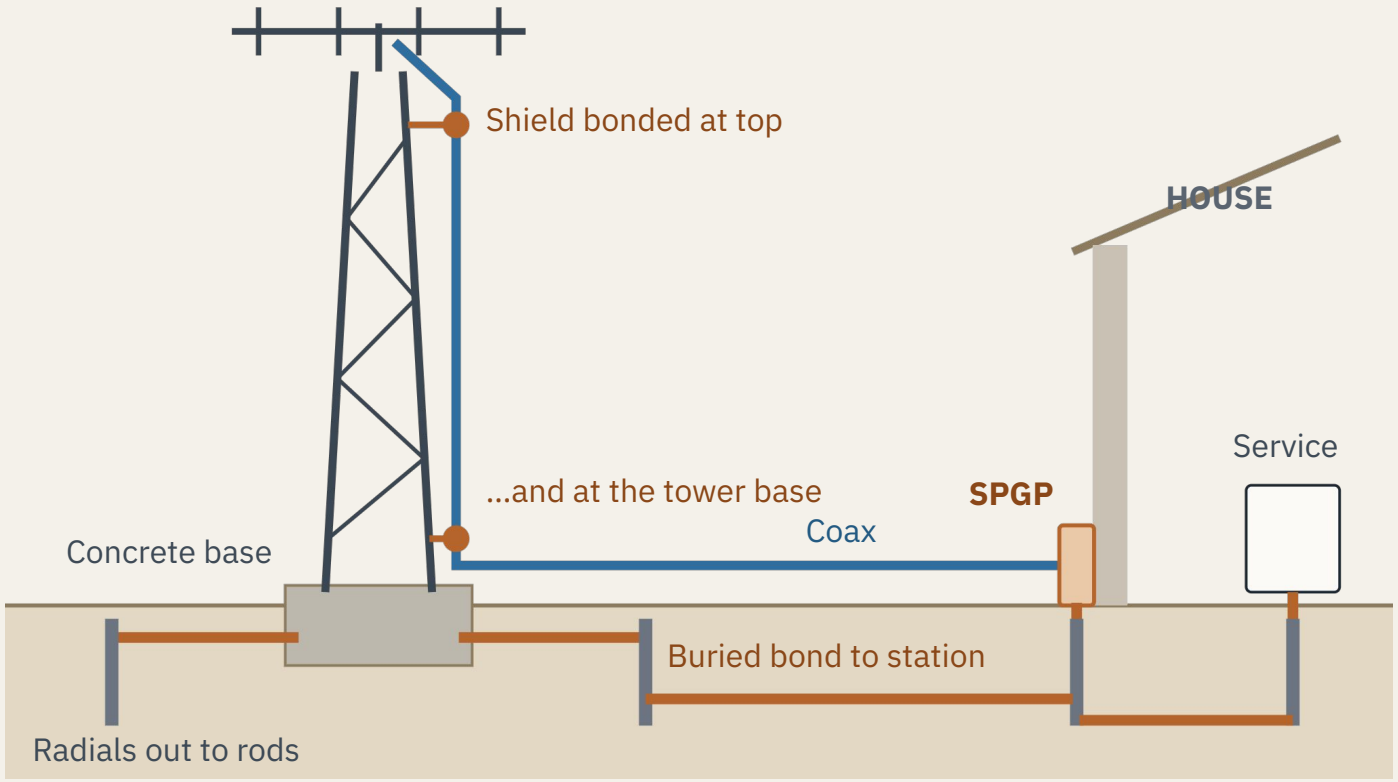
A coax T with λ/4 of coax shorted at its end. On its band it’s an open, so RF passes; lightning sees a short. Single-band antennas only.

Blue: RF to the radio. **Orange:** surge to ground. Mount each arrestor on the SPGP; no SPGP? Run solid copper, not braid, from its ground lug straight to the ground rod.

Ref: ARRL, Grounding and Bonding for the Radio Amateur; NEC 810.57, 810.58

TOWER GROUNDING

Give the strike many paths to earth

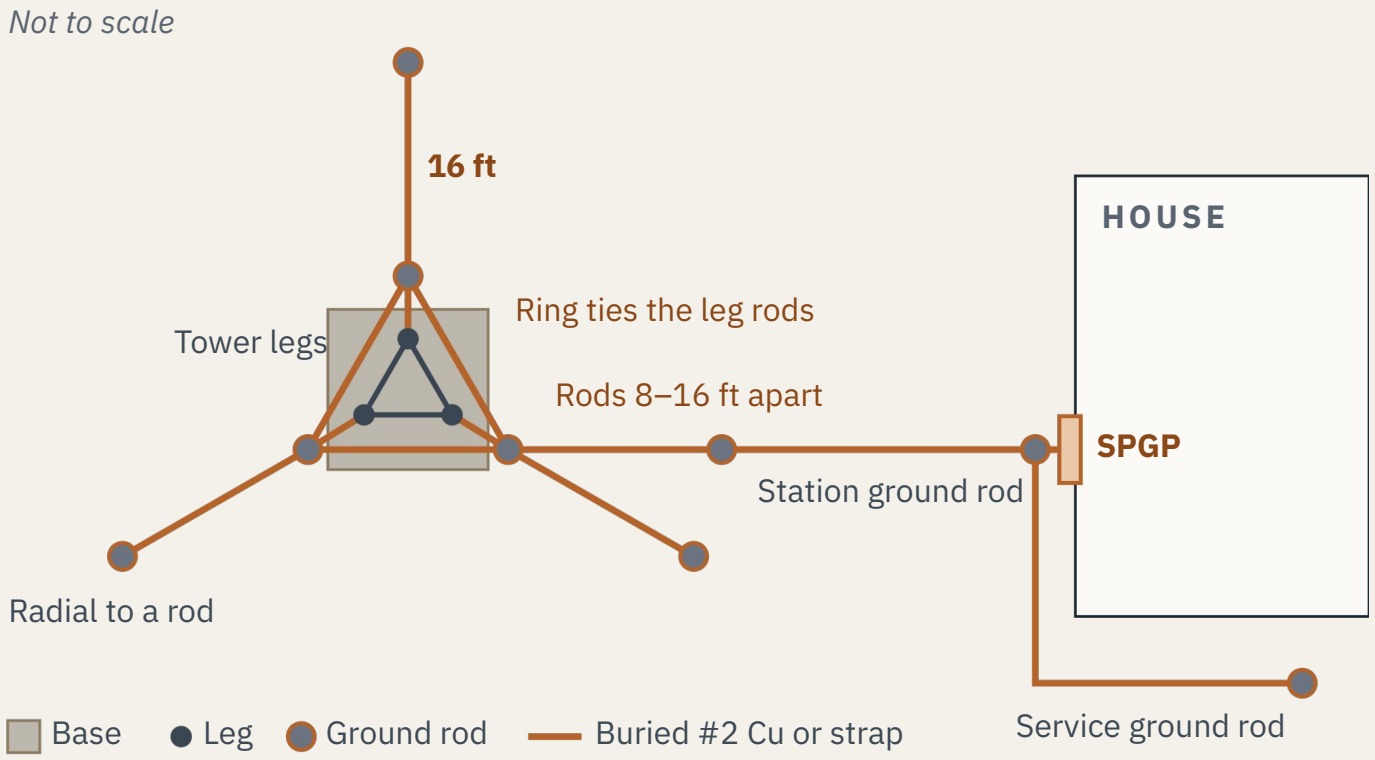


- Bond every leg to its own rod; add radials and more rods.
- Rods 8 ft apart at minimum; 16 ft is better.
- Ground the coax shield at the top, the base, and the entry panel.
- Tie the tower field to the station and service grounds. No islands.
- Listed clamps or exothermic welds. Never solder: it melts.

Ref: ARRL, Grounding and Bonding for the Radio Amateur; NFPA 780; Motorola R56

TOWER GROUNDING · TOP VIEW

A Rohn 25 ground field from above



A ground rod at each leg, strapped to the leg; a ring ties the three together.

Why radials: they spread strike current over more soil, so the base rises less.

A rod at the end of each; rods 8 ft apart minimum, 16 ft better.

A buried run to the house ends at the station ground rod and SPGP.

Bond to the service ground rod. Guyed? Ground each guy anchor too.

Ref: ARRL, Grounding and Bonding for the Radio Amateur; NR2B, QST 2002; Motorola R56

THE ELECTRICAL CODE

What NEC Article 810 asks of hams

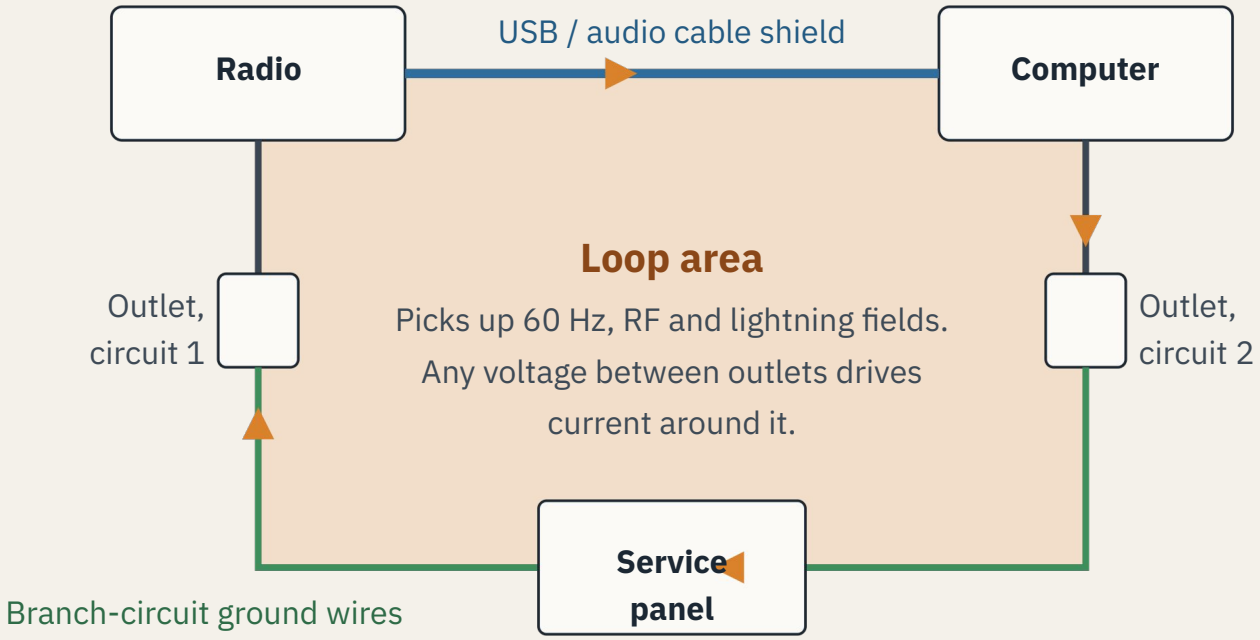
Requirement	Section	In practice
Antenna discharge unit on each lead-in conductor	810.57	Arrestors on the SPGP
Masts and metal antenna supports grounded	810.15	Includes towers
Protective grounding conductor: at least lead-in size, never under 10 AWG copper	810.58	Arrestor to ground rod
Operating (equipment) grounding conductor: 14 AWG copper minimum	810.58(C)	Strap does better
Grounding conductor run as straight as practicable, protected where exposed	810.21	Short, no loops
Any separate ground rod bonded to the building’s grounding system, 6 AWG copper minimum	810.21(J)	No isolated rods

The NEC is a **minimum** safety code, not a lightning design. Section numbers are from the 2017–2023 editions; newer editions reorganize some grounding rules. Your local inspector has the final word.

Ref: NEC Article 810, Parts I and III

GROUND LOOPS

Two paths to ground make a loop



Why they hurt

- Hum and buzz on audio; digital modes that won’t decode.
- RF in the loop: USB dropouts, hot audio, RFI.
- A nearby strike induces big current around a big loop.
- An unbonded rod is the worst loop: the surge goes through your gear.

Ref: ARRL, Grounding and Bonding for the Radio Amateur; K9YC, Power, Grounding, Bonding and Audio

GROUND LOOPS

Finding and fixing ground loops

Find it: unplug signal cables one at a time while listening. When the hum stops, that cable closes the loop.

1 · Strap the boxes together
A short strap carries loop current instead of the cable shield.

2 · One circuit, one strip
All cord grounds land at one point, so outlets can’t differ.

3 · Star, not daisy chain
Each chassis on its own strap to the bus, never box to box.

4 · Bond every ground rod
No isolated rods: station, tower and service are one system.

5 · Isolate the signal
Audio transformers, USB isolators or optical links break the loop.

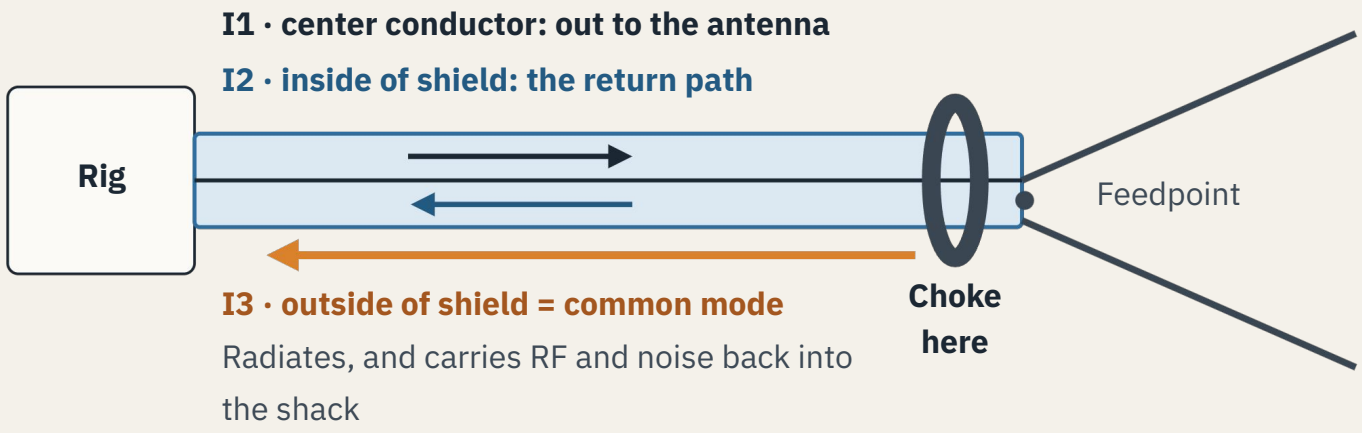
6 · Keep cables together
Run signal cables along the ground strap: less area, less pickup.

> **Never “fix” hum by lifting the AC ground pin.** It trades a noise problem for a shock hazard.

Ref: ARRL, Grounding and Bonding for the Radio Amateur; K9YC, Power, Grounding, Bonding and Audio

COMMON-MODE CURRENT

When the feedline becomes the antenna



Skin effect keeps the inside and outside of the shield separate at RF: the outside is just another wire.

Any imbalance at the feedpoint pushes current onto the outside of the shield.

Grounding helps: bond the shield at the tower base and entry panel so I3 drains to earth outside.

A bonded shack stops hot mics, RF burns and “bitey” chassis.

Where grounding stops helping: from an upstairs shack, a long ground wire is itself an antenna. That job needs a choke.

Ref: K9YC, RFI, Ferrites and Common Mode Chokes for Hams; ARRL Grounding and Bonding

COMMON-MODE CURRENT

Signs of RF where it doesn't belong

Mic bite
RF tingle or burns from the mic, key or chassis.

Resets
Rig, tuner or computer reboots or locks up on transmit.

USB dropouts
CAT, sound card or interface disconnects mid-QSO.

Keyboard, mouse
Stuck keys, phantom clicks or a jumpy cursor on TX.

Monitors
Flicker, lines or a blank screen while transmitting.

The house
TV, stereo, phones or touch lamps react to your signal.

Touchy SWR
SWR changes when you touch or move the coax.

Audio reports
Distorted or buzzy transmit audio on some bands.

> **Clue:** if it happens on some bands or power levels and not others, a feedline or ground lead is resonant there.

Ref: K9YC, RFI, Ferrites and Common Mode Chokes for Hams; ARRL RFI Book

GROUND AUDIT · PART 1

A 20-minute walkaround with a flashlight

Outside

- Service ground rod: clamp tight, clean and listed; GEC intact.
- Every ground rod (tower, SPGP, station) bonded back to the service ground rod.
- Arrestors bolted to the grounded bus; no corrosion, no cracked cases.
- Tower legs strapped; coax shield bonded at the top and the base.
- No solder joints, coiled wire or sharp bends anywhere in the path.

Inside

- Every chassis has its own strap to the bus; no daisy chains.
- Bus strapped to the SPGP or window panel, short and direct.
- All cords 3-prong; no cheater plugs or clipped ground pins.
- Station on one circuit and one real surge strip (UL 1449).
- Ferrites where cables leave the desk; give every clamp a tug.

Ref: ARRL, Grounding and Bonding for the Radio Amateur; NEC 250, 810

GROUND AUDIT · PART 2

Verify it: simple tests, clear targets

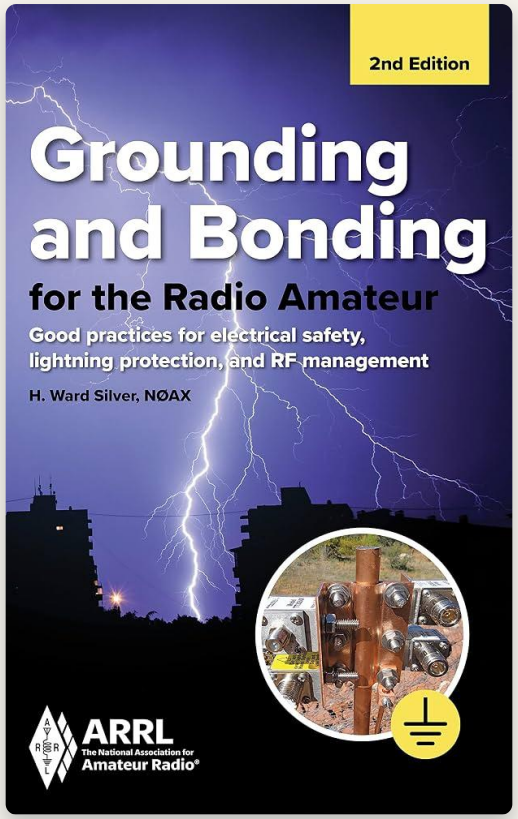
Test	Tool	Good result
Outlet wiring at the station	3-light receptacle tester	“Correct” (can’t spot a bootleg ground)
Voltage, station bus to outlet ground pin	Multimeter, AC volts	Essentially 0 V
Bonding, station bus to outlet ground pin	Multimeter, ohms (leads zeroed)	Well under 1 Ω
Each ground rod to earth	Clamp-on or 3-pole earth tester	25 Ω or less for one rod (NEC); lower is better
Common-mode current on coax and cables	Clamp-on RF current probe, while transmitting	As close to zero as you can get
Quick common-mode check	Touch or move the coax at low power	SWR and audio don’t change

> **Never disconnect a ground to test it** while the service is live; that’s what clamp-on testers are for. Re-audit yearly and after any nearby strike. Our dry summers raise earth resistance.

Ref: NEC 250.53(A)(2); Motorola R56; K9YC

LEARN MORE

References and further reading



ARRL

- **Grounding and Bonding for the Radio Amateur**, 2nd ed., H. Ward Silver, N0AX: the main reference for this talk
- Companion page: arrl.org/grounding-and-bonding-for-the-amateur
- ARRL Technical Information Service: Electrical Safety, Grounding and Lightning Protection
- *The ARRL RFI Book* and *The ARRL Antenna Book*

Articles and papers

- Ron Block, NR2B, “Lightning Protection for the Amateur Radio Station,” QST, June–August 2002
- Jim Brown, K9YC, “Power, Grounding, Bonding and Audio” and “RFI, Ferrites and Common Mode Chokes for Hams” (k9yc.com)

Codes and standards

- NFPA 70, National Electrical Code: Articles 250 and 810 (free to read online at nfpa.org)
- NFPA 780, lightning protection · Motorola R56, communication site standard

TAKEAWAYS

Bond it, protect it, disconnect it

Questions? 73 de K7AKT

Do

- Bond everything to one point
- Bring every cable in through the SPGP
- Keep ground runs short, straight and wide
- Bond the coax shield at the tower and the entry
- Audit yearly; disconnect for storms and trips

Avoid

- An isolated “radio ground” rod
- Daisy-chained chassis grounds
- Coiled excess wire and sharp bends
- Solder joints in the lightning path
- Using the outlet ground as your lightning ground

> No grounding system guarantees survival of a direct strike. **Disconnecting is still the best protection.**