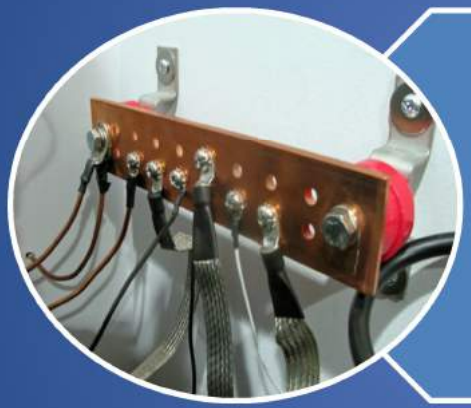
Station Current Control a.k.a. Grounding



de VE6KK

Peter

SASTAR talk Feb 22, 2021

Not intended as an engineering guide – consult qualified advisors.

WHERE DO I START?

The Great Ground Mystery

What is a "Ground"?

- RF? AF? AC power? Lightning? signal?

What is a "Ground Loop"?

- this could drive us loopy

So called grounding is an engineering problem!

- optimization: safety, performance, cost
- we must use a systems approach
- our station should be planned for growth, improvement

In part 1 we will look at basics

- what currents, what paths?
- understand the effect of unwanted currents

So what do we do about it?

In part 2 we will build up a station

- with an eye to controlling currents
- to optimize safety and performance

Back-ground: What is "Grounding?"

Whether we like it or not:

We have many currents sharing common conductors

1. there is nothing mysterious or magical about "ground"
2. common conductors should present a low Z path for intended currents but block or dissipate unwanted currents
3. common paths ("grounds") can be compatible
4. common path systems must be carefully integrated
5. we must plan the entire system for common conductors

Confusing and conflicting information

This looks fine to me! - or does it? (this picture is very misleading)

Can you get your foot caught in a ground loop?

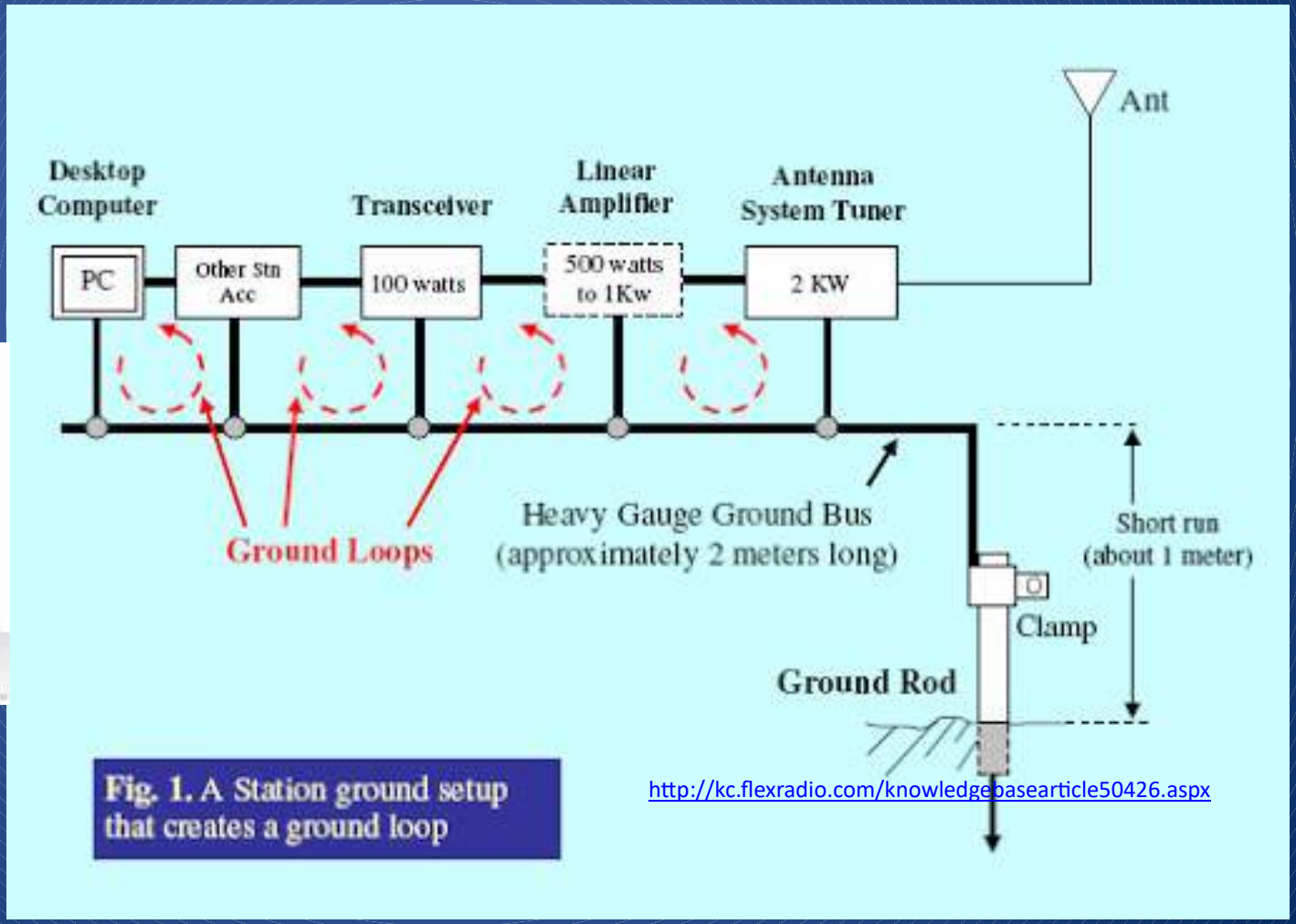


Fig. 1. A Station ground setup that creates a ground loop

http://kc.flexradio.com/knowledgebasearticle50426.aspx

Part 1. Basics – stuff we know?

Current

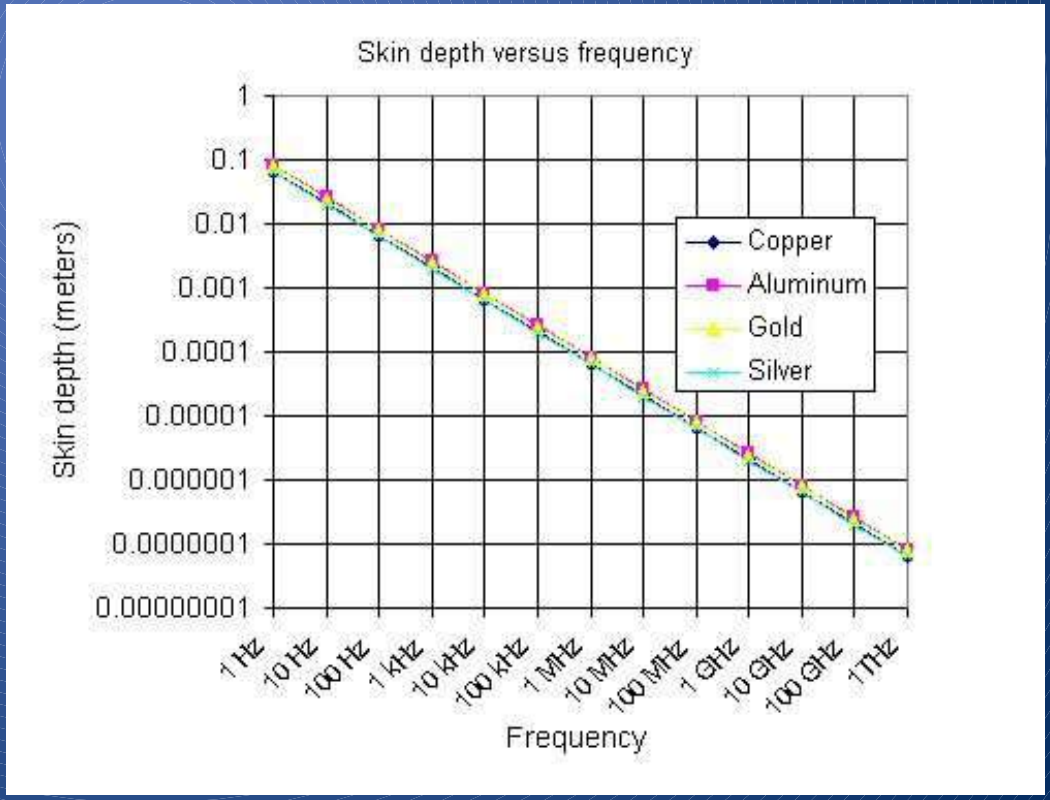
- a flow of DC AC or an impulse <<charge, discharge
- where do we want or not want currents?
- conducted or induced
- can generate fields

Voltage

- a potential difference
- exists only due to current flow or static charge

Skin Effect

- important for low Z RF paths
- braid or strap is useful
- not a great concern for AC power or lightning

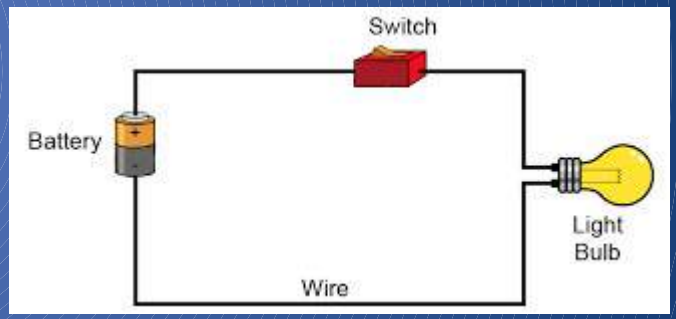


Inductance

- opposition to current change
- micro Henries matter!
- can be used for current control!
  i.e. choke unwanted RF currents
- could cause lightning HV rise

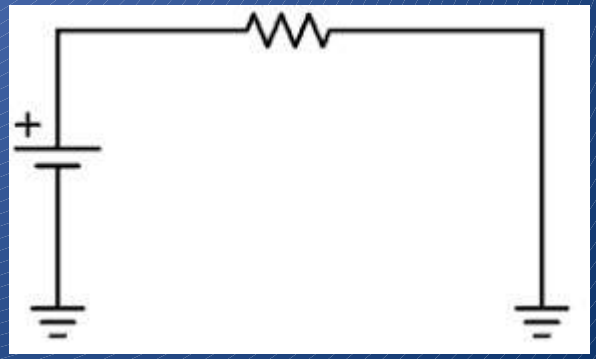
Reactance

- opposition to AC but no power lost
- types inductive or capacitive reactance



Complete circuit

- what we usually expect
- even antenna RF or lightning
  though not continuous



Grounding

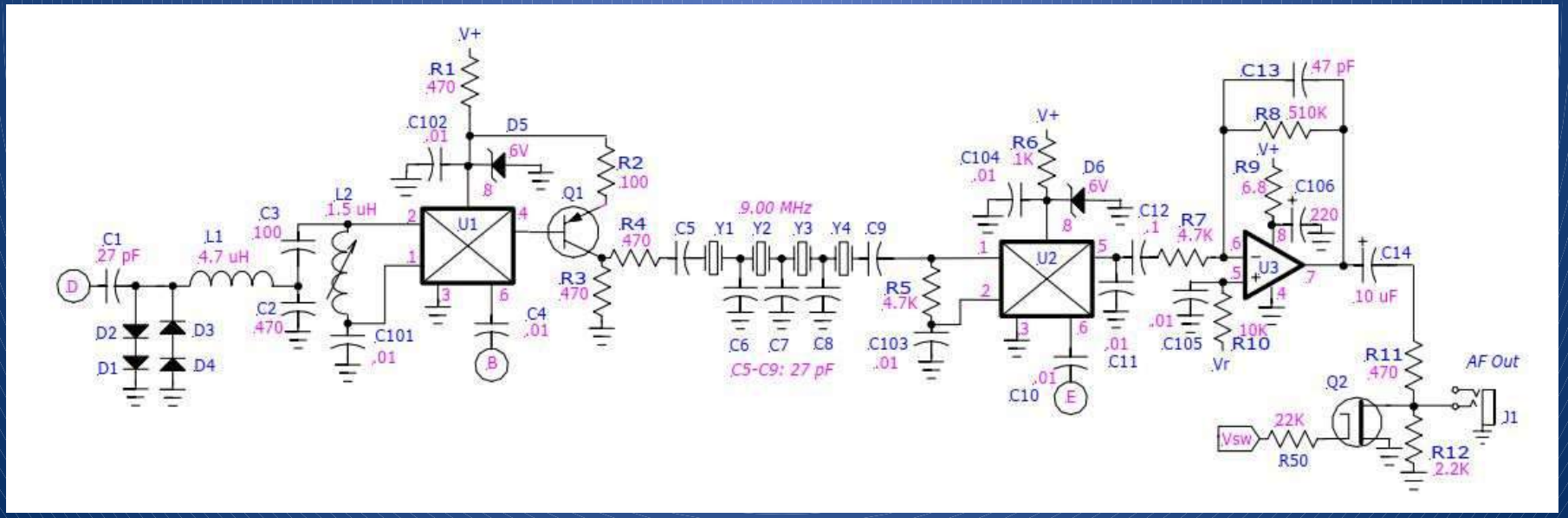
- often misunderstood
- a path for “return” currents

To repeat – grounding is…

- often misunderstood
- a path for return currents

Complete circuit showing grounds

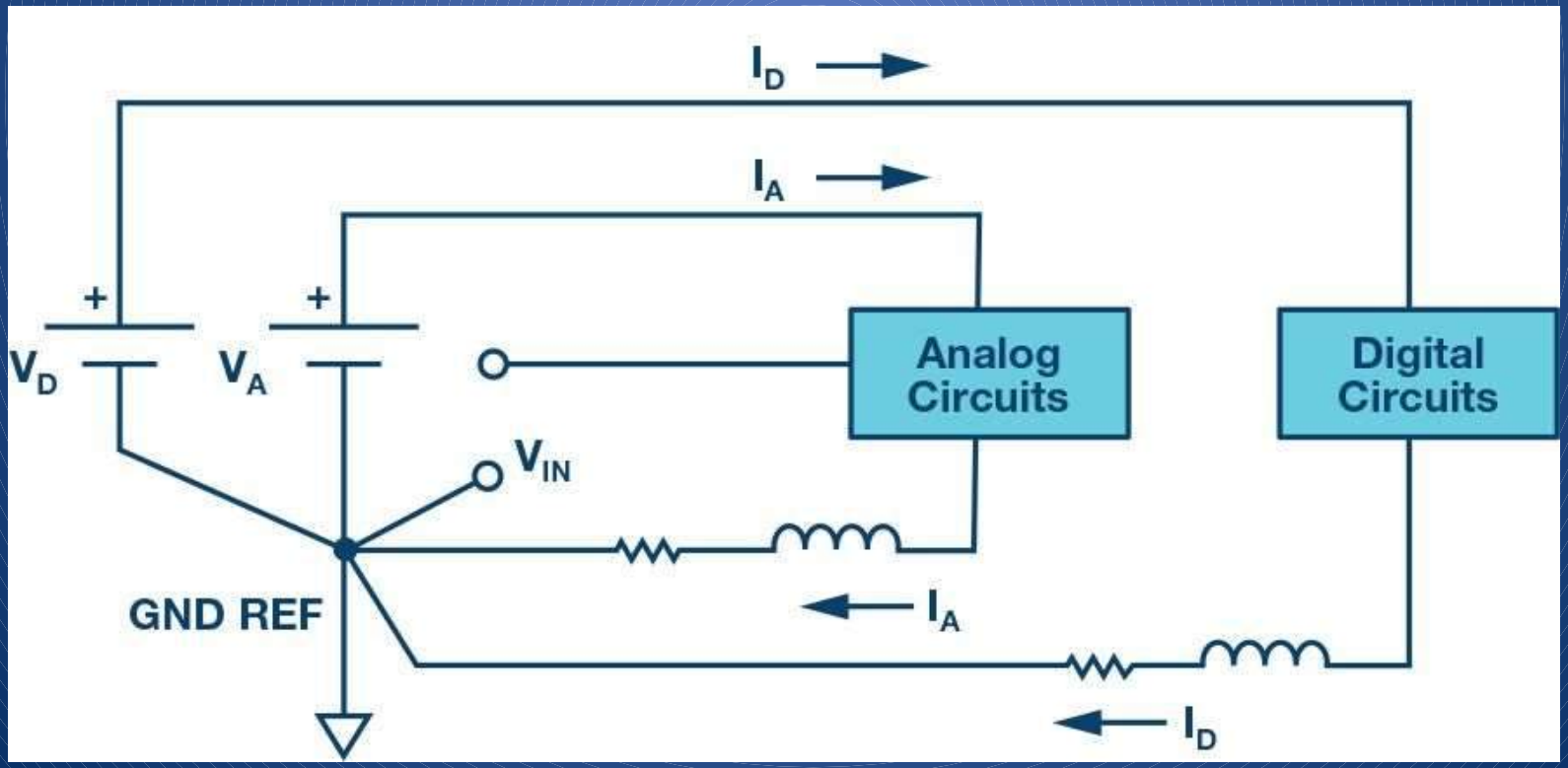
- Small Wonder Labs PSK receiver
- “ground” carries AF, RF, DC bias, maybe AC line hum
- it could be a chassis, PC board “plane” or single point
- as long as “ground” has no resistance or inductance all is well ☺



…as long as “ground” has no resistance or inductance…

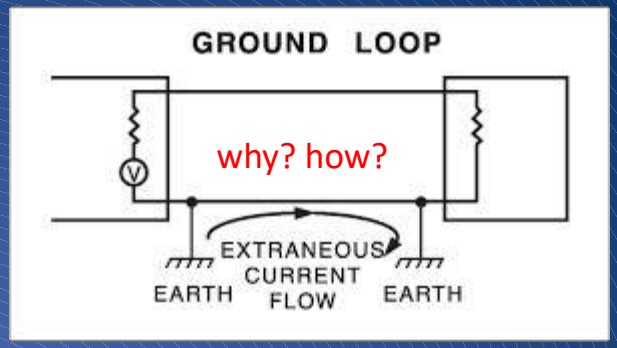
Single point grounding example

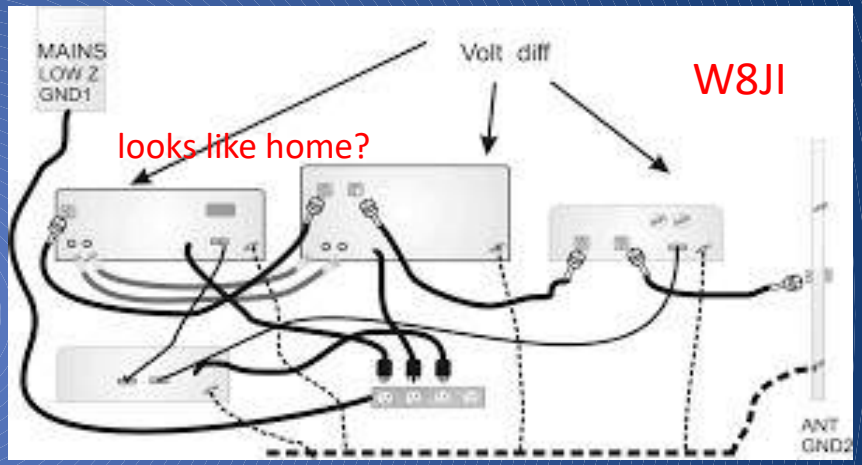
- digital devices have current spikes which can get into analog circuits
- good bypassing may be all that is needed
- a full treatment uses a single point ground:
  - analog and digital circuit commons are connected together at one point
- any voltage drop in one return lead does not affect the other circuit



Ground Loop

- a needlessly confusing term
- any complete circuit is a loop!
- it is really a common current pathway
- it may be inevitable but not always zero resistance or inductance
- current in one path may combine with current in another = trouble





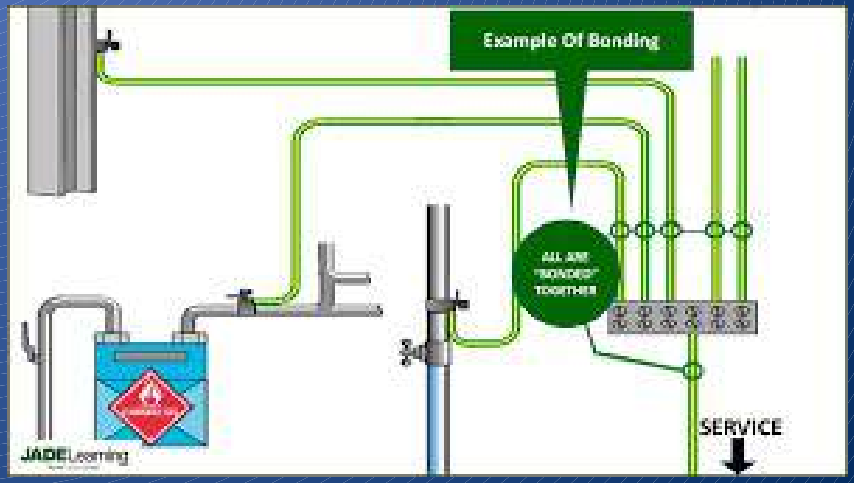
Bonding

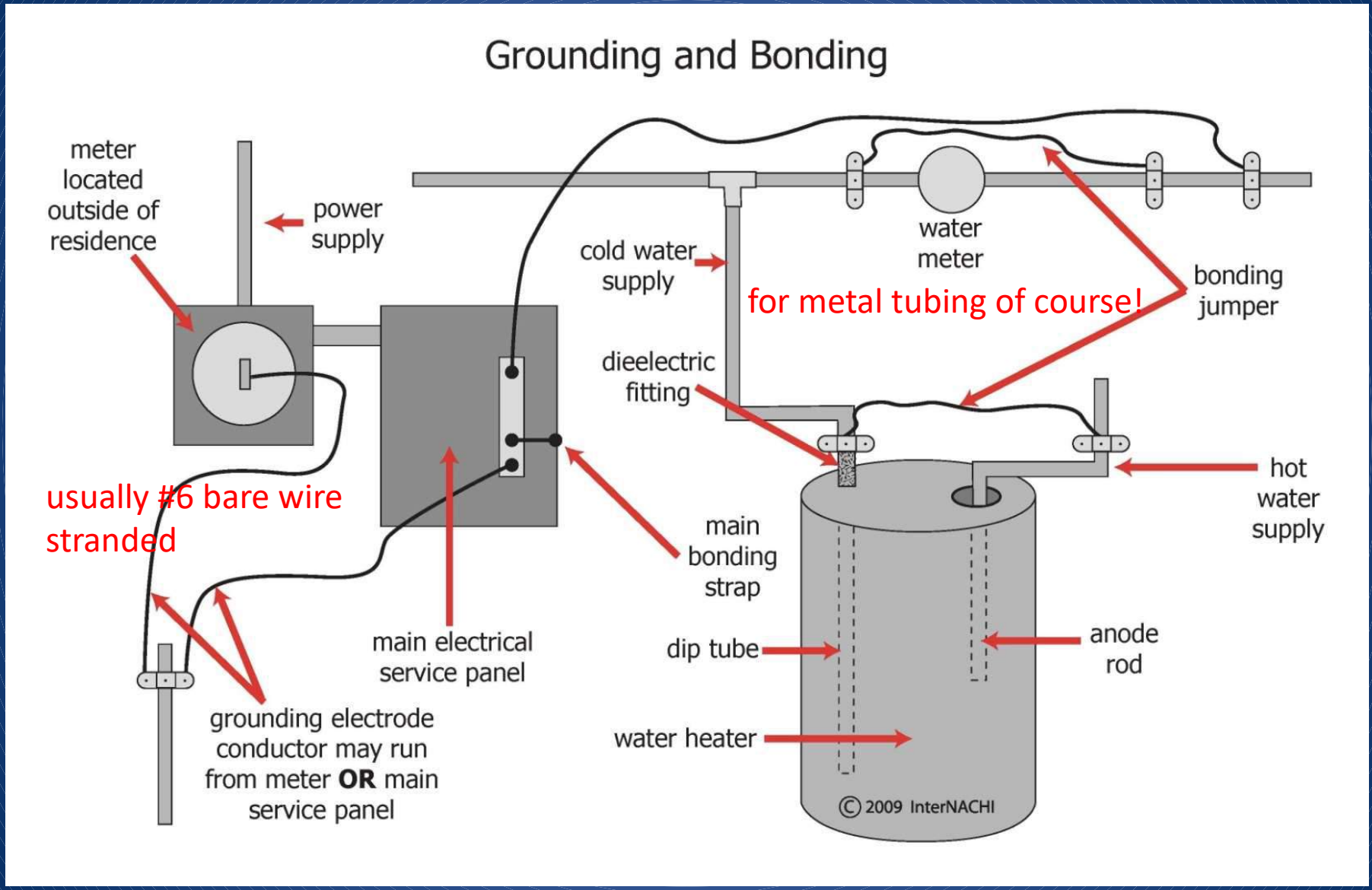
DC AC or an impulse

- electrical industry term
- means “connected together”

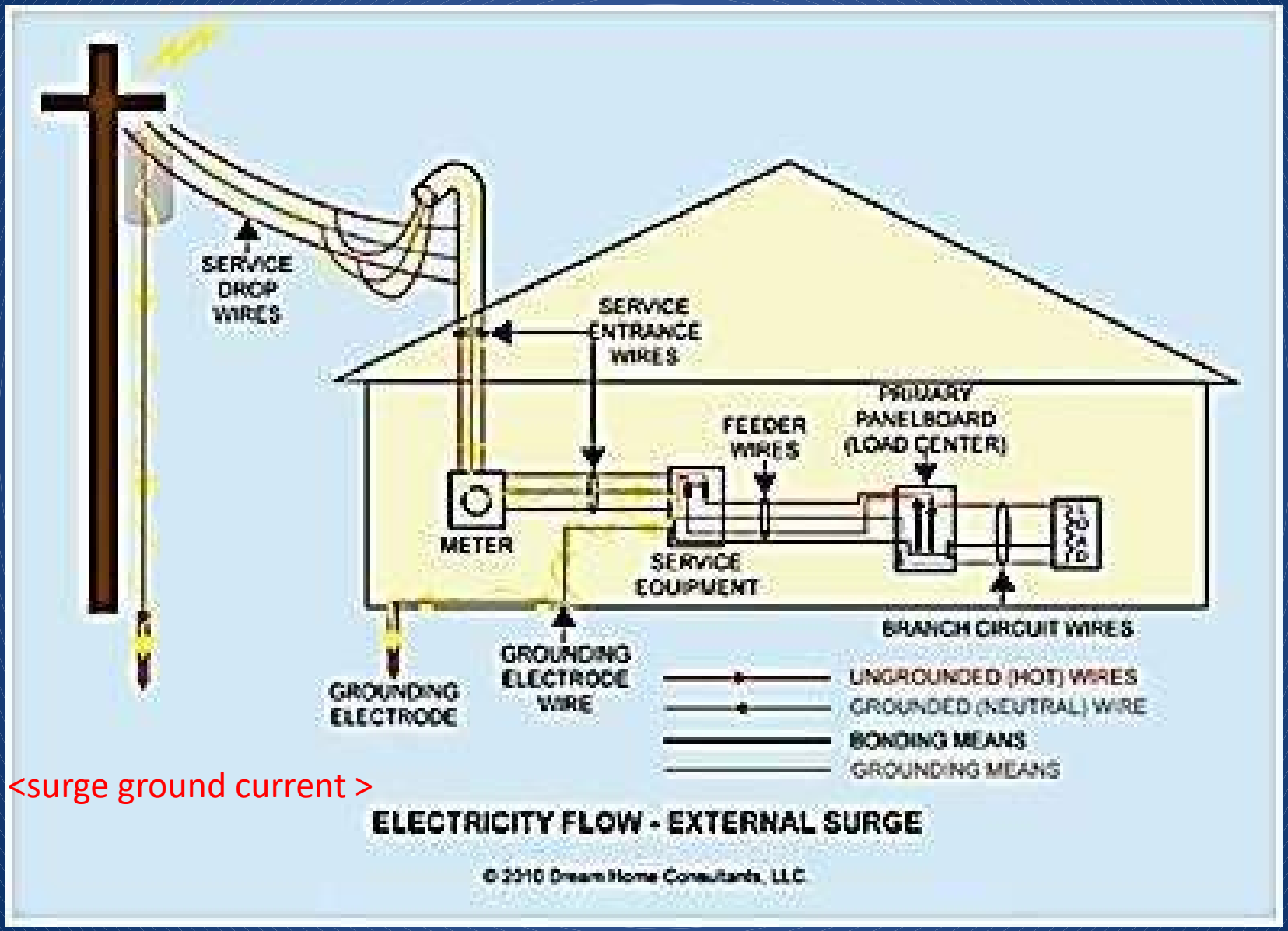
AC mains safety ground

- ground rods or plate (see CEC)
- tied to Neutral at panel only
- only one ground permitted
- carried to all equipment via bonding
- should not have current flow, but…




Grounding and Bonding
meter located outside of residence
power supply
cold water supply
water meter
bonding jumper
for metal tubing of course!
dieelectric fitting
hot water supply
usually #6 bare wire stranded
main bonding strap
main electrical service panel
dip tube
anode rod
grounding electrode conductor may run from meter OR main service panel
water heater
© 2009 InterNACHI

What should happen during a powerline surge



<surge ground current >

How lightning causes damaging currents

- think 20 kA in 20 microseconds multiple fast pulses
- strike may be indirect and do severe damage
- high earth currents can cause damaging voltage drops

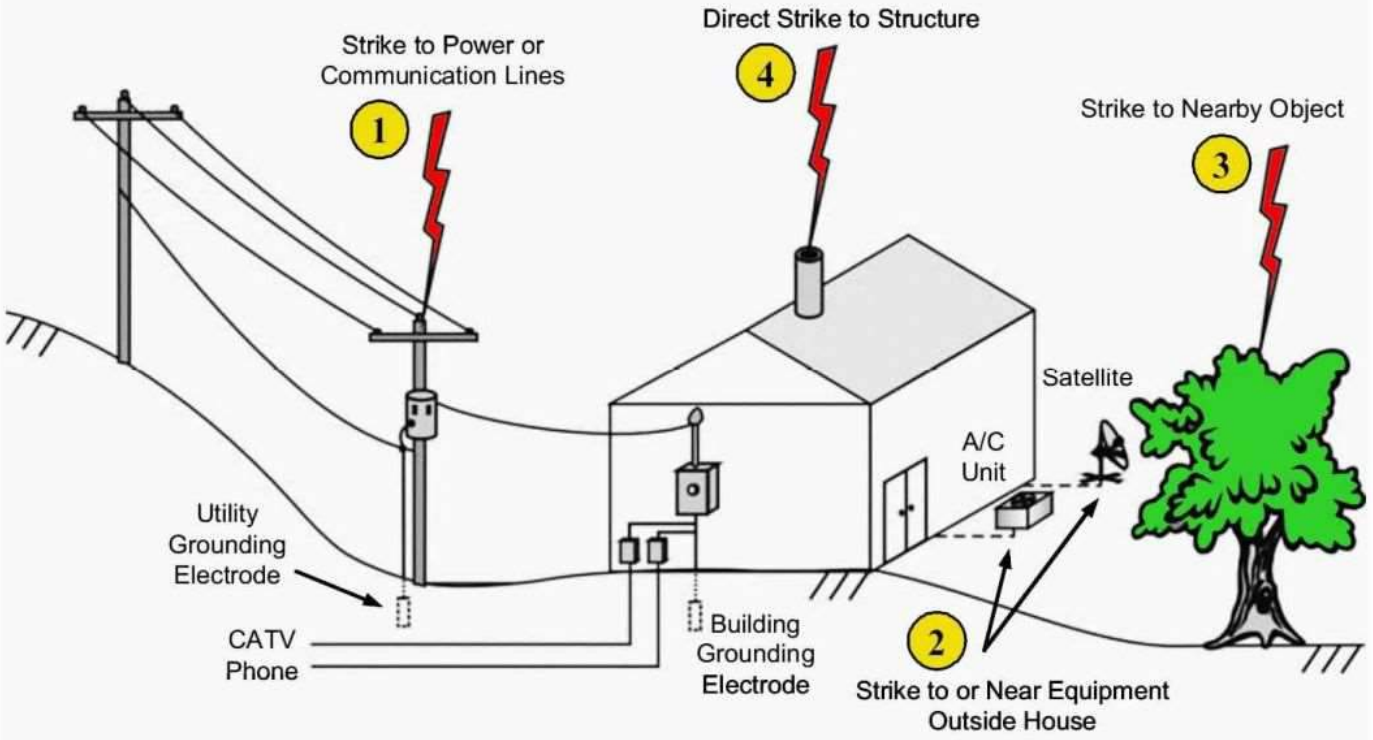


Figure 1 – How Lightning Creates Damaging Voltages Inside the Home. The most common source of damage is from strikes to power and communications lines, which then conduct the surges directly into the equipment. Direct strikes to the building, while rare, can damage the structure as well as the contents.

GROUNDING NOTES

de VA7JW

Ground means EARTH

When using arrestors, divert the lightning currents on conducting cables as directly to earth as physically possible, and keep them OUTSIDE OF THE BUILDING. Lightning arrestors of any and all sort will be of little use if not directly earthed.

Lightning currents will find the lowest IMPEDANCE path to earth. Given the extremely fast rise time of lightning currents, measured in kA/usec, it is the impedance (R+X) of the grounding system that dominates, not the DC resistance. DC resistances may be 1 – 10 milliohms / foot, and so a 10 kA current would develop 10 to 100 V per foot of length. The inductance of the wire is much more significant. AWG # 6 copper, straight, has a self inductance of about 0.3 microhenries per foot. Given the inductance equation,

$$V = L \, di/dt$$

GPR kV!

where di/dt is the rate of change of current over a specified time interval at 10 kA/usec, and L is the inductance. The calculated voltage potential along the length of line would be 3kV per foot. This is far greater than the resistance voltage gradient thus inviting flashover.

SHORT, STRAIGHT conductors are best as even a right angle turn in the wire increases inductance and therefore impedance, resulting in a local high voltage and possible flashover at that point.

In terms of current carrying capacity, the Canadian Electrical Code requires that grounding wire must be no smaller than #6 AWG stranded copper. From a lightning perspective, this size of wire will fuse, meaning it is on the verge of melting, if conducting 200 kA for ~ 1 msec [5]. This usually provides sufficient margin as the peak strike currents are of less duration and magnitude. Duration vs. Current specs for #6 as follows.

668 A / 10 sec	3.8kA / 1 sec	21 kA / 32 msec

Ground Potential Rise (GPR)

- conductors have resistance and inductance
- large capacitance to be charged in a short time
- GPR can result in arcs through cables or equipment

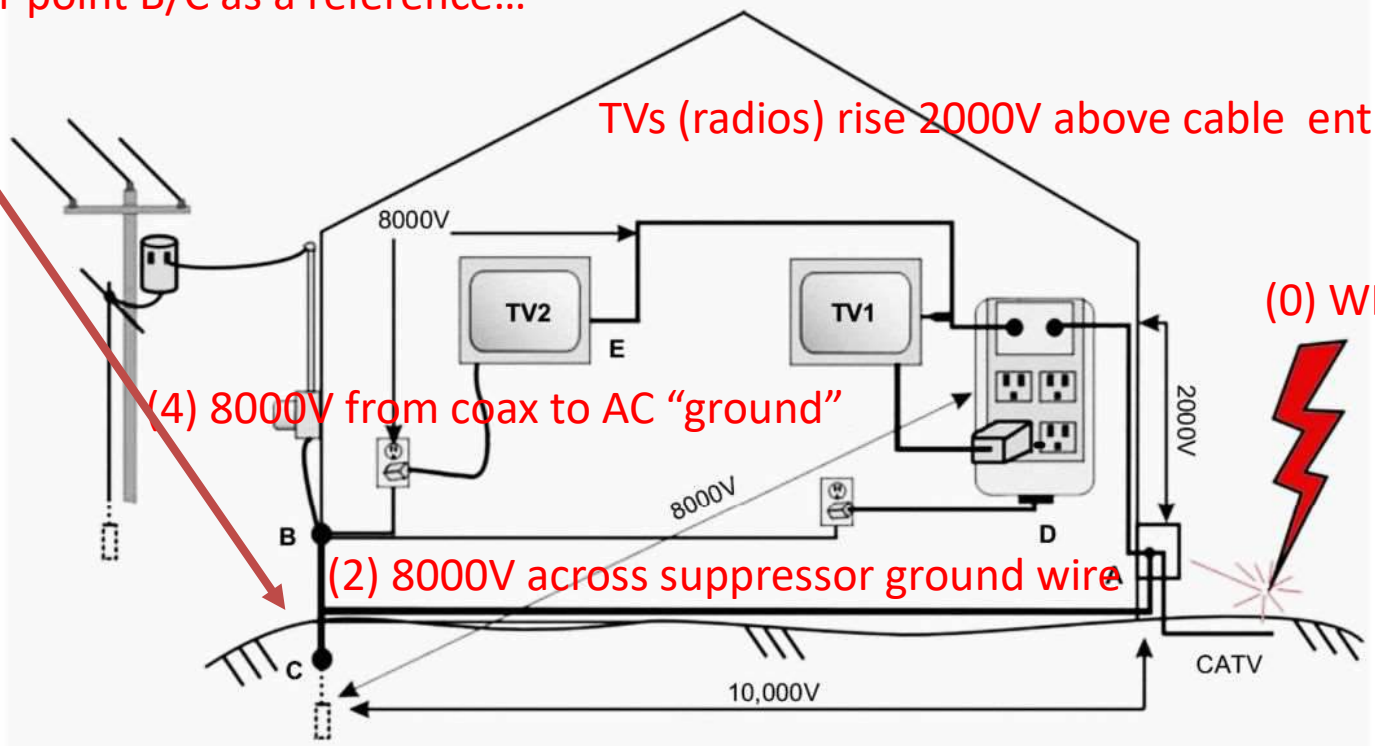


Figure 6 – Ground potential differences within a building under lightning strike conditions

Lightning protection

- heavy conductors straight to ground
- integrated bonding to power and RF grounds
- get professional advice also re insurance
- add a tower as a lightning rod?

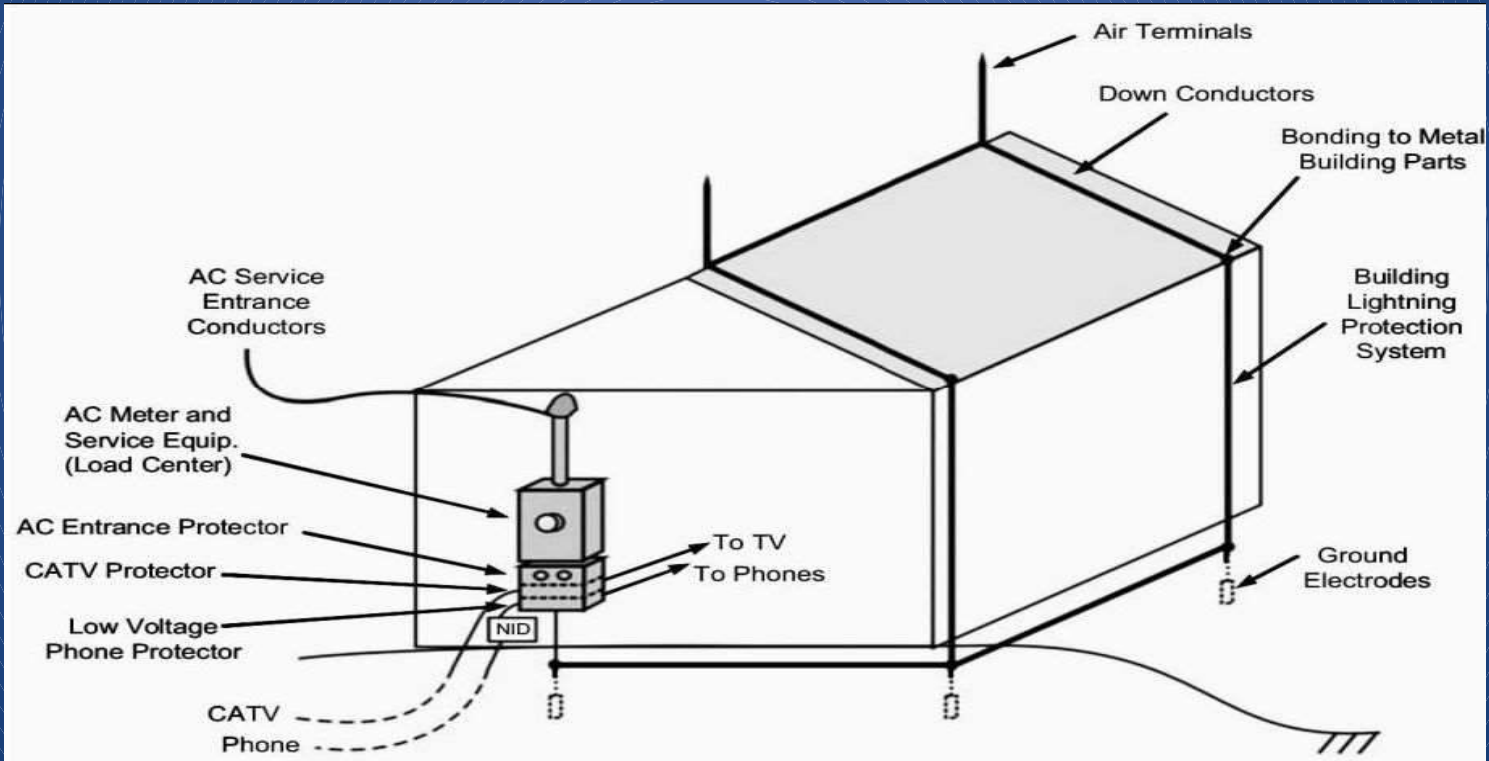


Figure 2 – Additional Protection Described by NEC. The NEC allows the addition of air terminals ("lightning rods"), bonded to the building ground, and additional AC protectors, coaxial protectors, and telecom protectors. The three ground electrodes and the bonds between them form the building ground electrode system.

Intended current paths:

1. **AC powerline wiring**
   - includes both heavy main and smaller safety wiring
   - conductors must be: low Z for 60,120 Hz, harmonics
   - need not (should not?) pass RF
   - doubles as low R path to reduce possibility of GPR due to lightning
2. **Lightning protection conductors**
   - conductors are low R but currents are very short in duration
   - must be low inductance also or else HV will develop an arc path
   - should be integrated with (bonded to) RF and power common
3. **RF conductors, shielding and bonding**
   - EM induced currents should pass freely back to antenna (source)
   - transmission line currents should stay in/on transmission line
4. **DC (12V) station bus**
   - best isolated from other commons but also well bonded
5. **Telephone and LAN wiring**
   - must be kept balanced and of proper Z
   - intrudes into other equipment that must be protected

Unintended current paths:

1. **AC powerline**
   - may forward unwanted HV spikes or common mode RF
   - need not (should not?) pass RF
   - line filters e.g. UPS recommended
   - added toroid/bead chokes may be needed
2. **Lightning conductors**
   - compatible with and similar to RF shielding aims
   - few unintended currents, can only improve situation
3. **RF conductors, shielding and bonding -** a big concern
   - keep RF off the outside of shields and enclosures
   - prevent RF travelling via common conductors
   - TX RF “pickup” is unintended but must be dealt with
   - in reverse the same issue results in extra RX noise
4. **DC station bus**
   - heavy conductors, good connections reduce problems
   - station supply filtering should bypass all RF
   - still good to keep DC bus away from grounding bus
5. **Telephone and LAN wiring**
   - ripe for HV transients and RF
   - use surge protection and RF chokes (don’t choke ADSL)

And one more…..Cross Coupling (next slide)

- called crosstalk when between cable pairs
- also leakage through coax shielding
- via capacitive coupling (voltage difference)
- or inductive coupling (changing currents)
- also called **common mode** interference
- typical problem: antenna displacement (space) currents induce RF on the outside of coax or other common conductors

How does this affect us?

- common "grounding" conductors carry currents
- may induce noise or RF into other conductors
- outside power or noise RF may enter shack, not good

What to do?

- maintain balance in telephone, LAN; also good shields on coax
- avoid close parallel runs between conductors which are not bonded
- space AC power runs physically where possible or run in EMT
- space DC power bus from RF tie "ground" bus but bond at one point
- provide as much spacing as possible between antenna fields and shack

Common mode currents

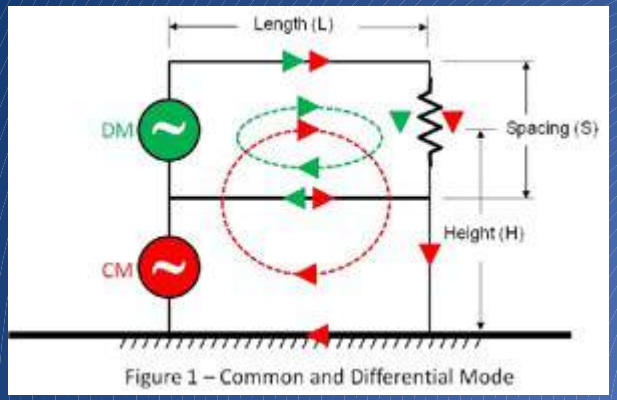
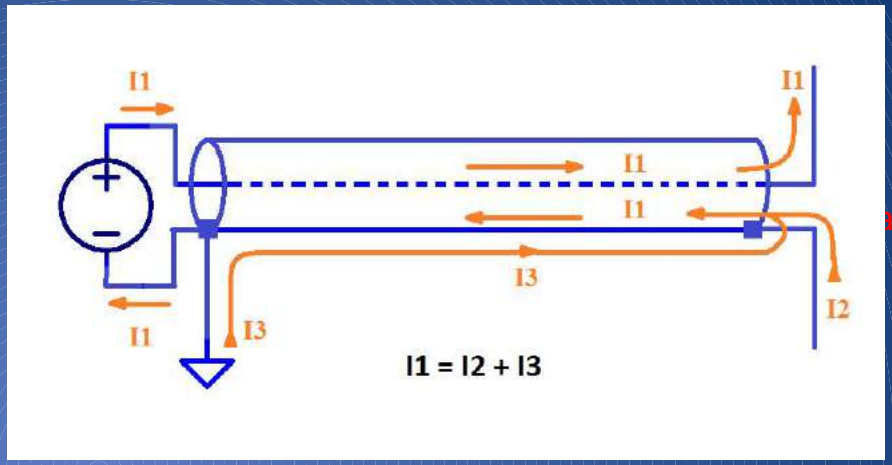
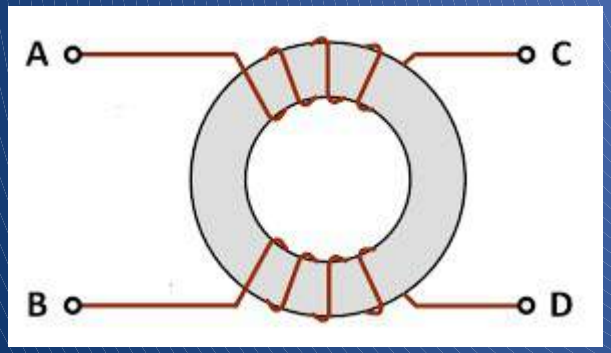
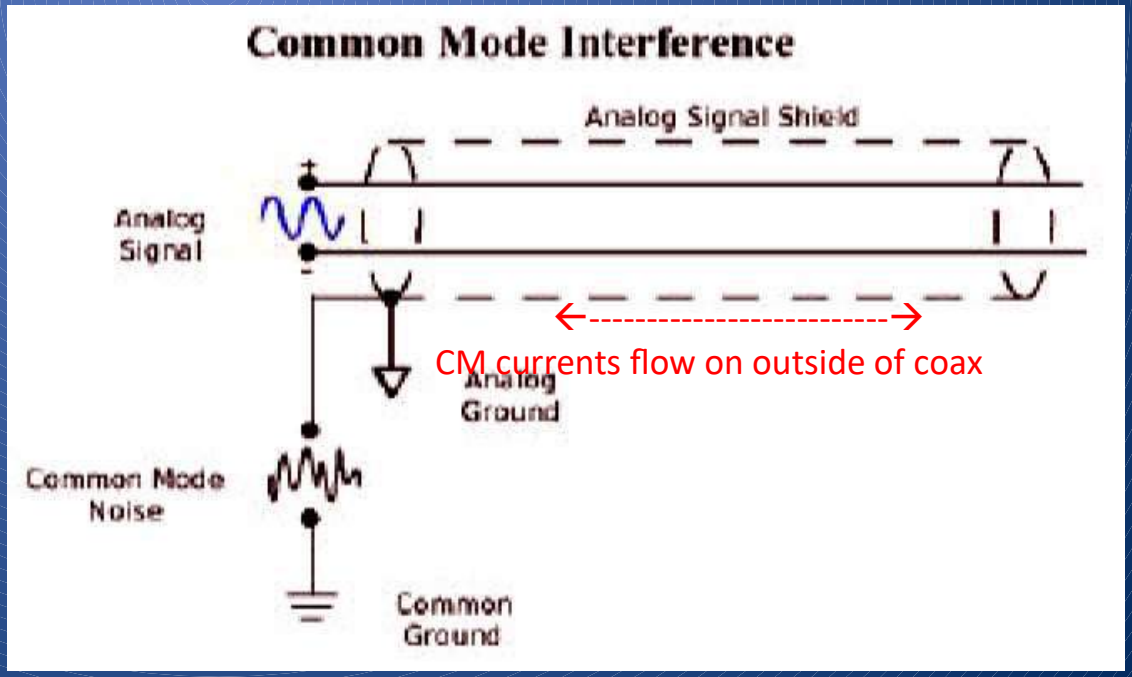


Figure 1 – Common and Differential Mode



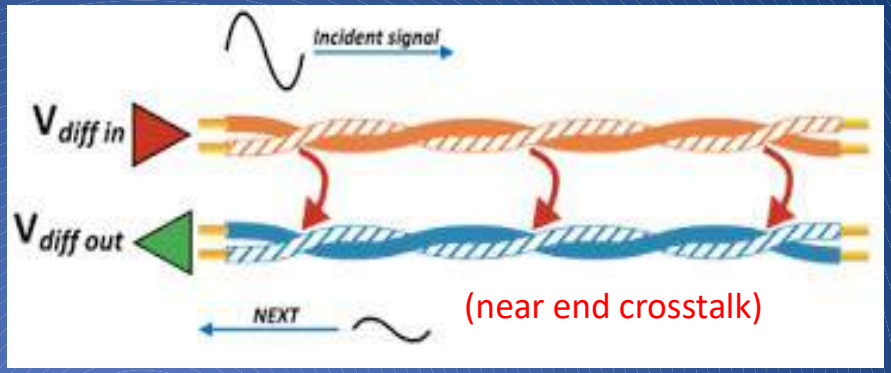


common mode choke
(balanced line)



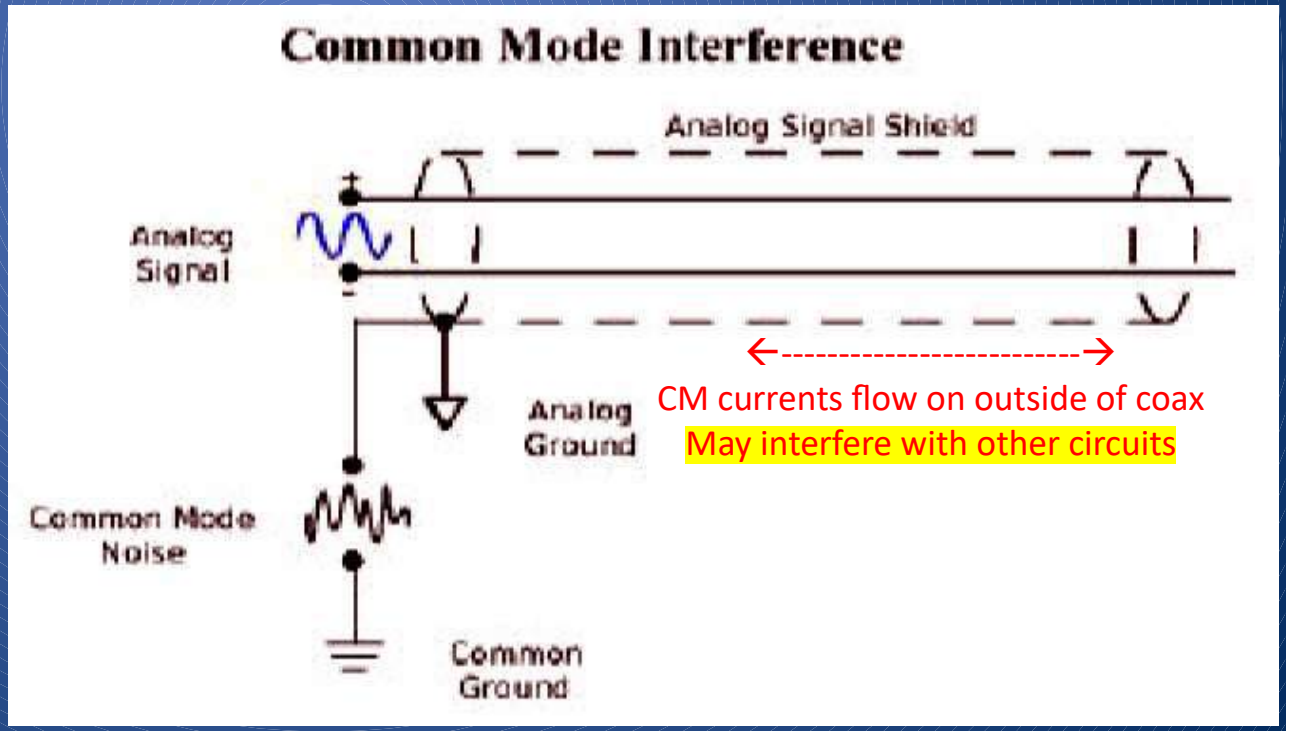
Cross coupling or Crosstalk

Twisted pair crosstalk
(due to imperfect balance)



(near end crosstalk)

Currents leak to outside of coax or are induced



←----------→
CM currents flow on outside of coax
May interfere with other circuits

Conclusions – part 1

To review:

We have many currents sharing common conductors

1. there is nothing mysterious or magical about "ground"
2. common conductors should present a low Z path for intended currents but block or dissipate unwanted currents
3. common paths ("grounds") can be compatible
4. common path systems must be carefully integrated
5. we must plan the entire system for common conductors

So what do we do about it?

In part 2 we will build a station

- with an eye to controlling currents
- to optimize safety and performance

Your mental homework

- where does ESD (static damage) fit in?

Part 2. Your Station

#1 The little station that could…

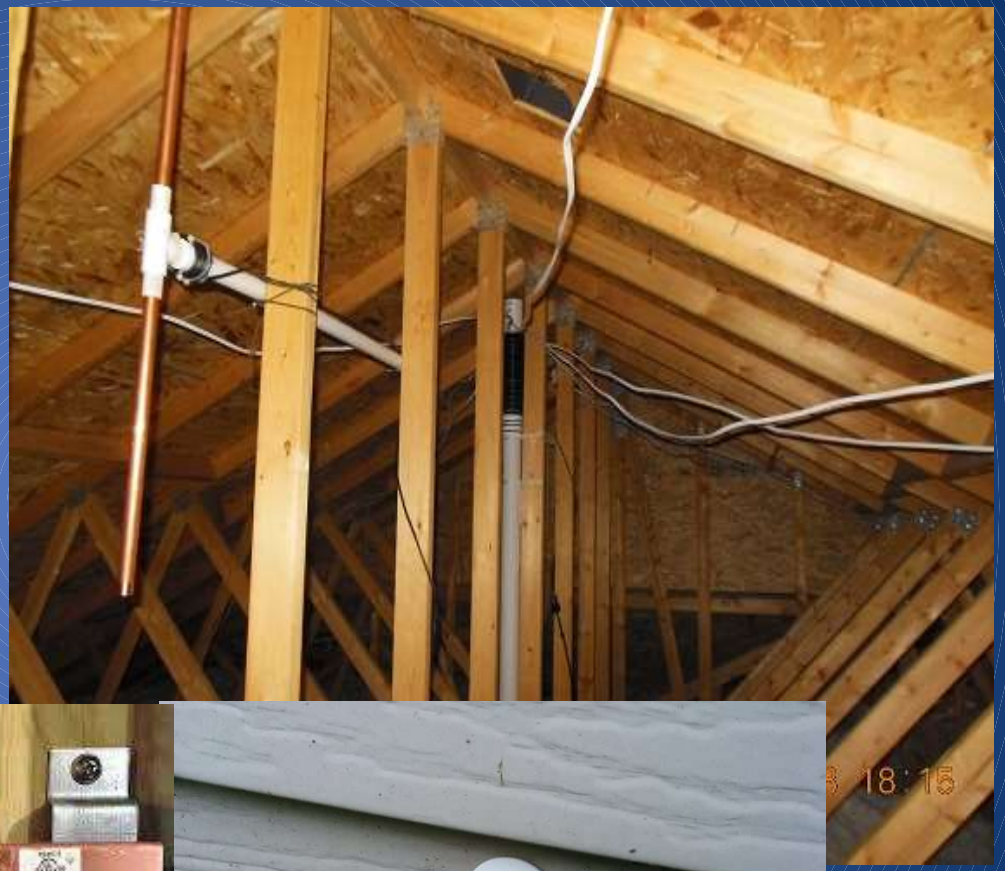
- Steve/wGØAT on a hill doing SOTA
- where are his common or grounding conductors?
- safety?
- RF return paths?
- sunscreen?
- 5 paths?

1. **AC powerline**
2. **Lightning conductors**
3. **RF conductors, shielding, bonding**
4. **DC station bus**
5. **Telephone and LAN wiring**

#2 Let's bring that radio in the house

- now we have a radio with external 13.6 V power supply
- VHF vertical in the attic
- AC power from power bar
- 5 paths? - likely no problems

1. **AC powerline - more exposed**
2. **Lightning conductors – nil – safe?**
3. **RF conductors, shielding, bonding -single coax, no meters**
4. **DC station bus - nil**
5. **Telephone and LAN wiring – nil**



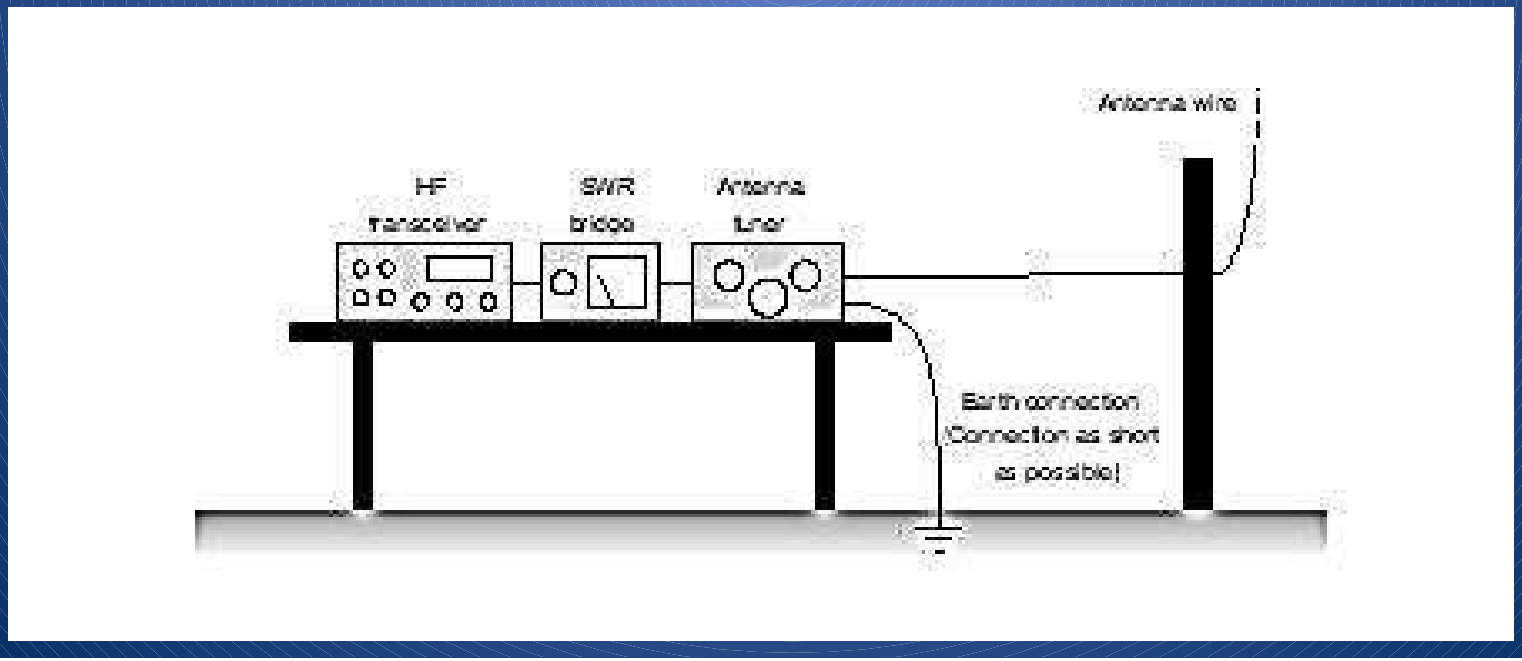
VHF at low power is not as prone to causing RFI or TVI and not as susceptible to noise from power conductors, LAN, telephone.

Some form of lightning conductor might be connected to coax shield at antenna. Run to outside if possible.

#3 Now add HF antennas

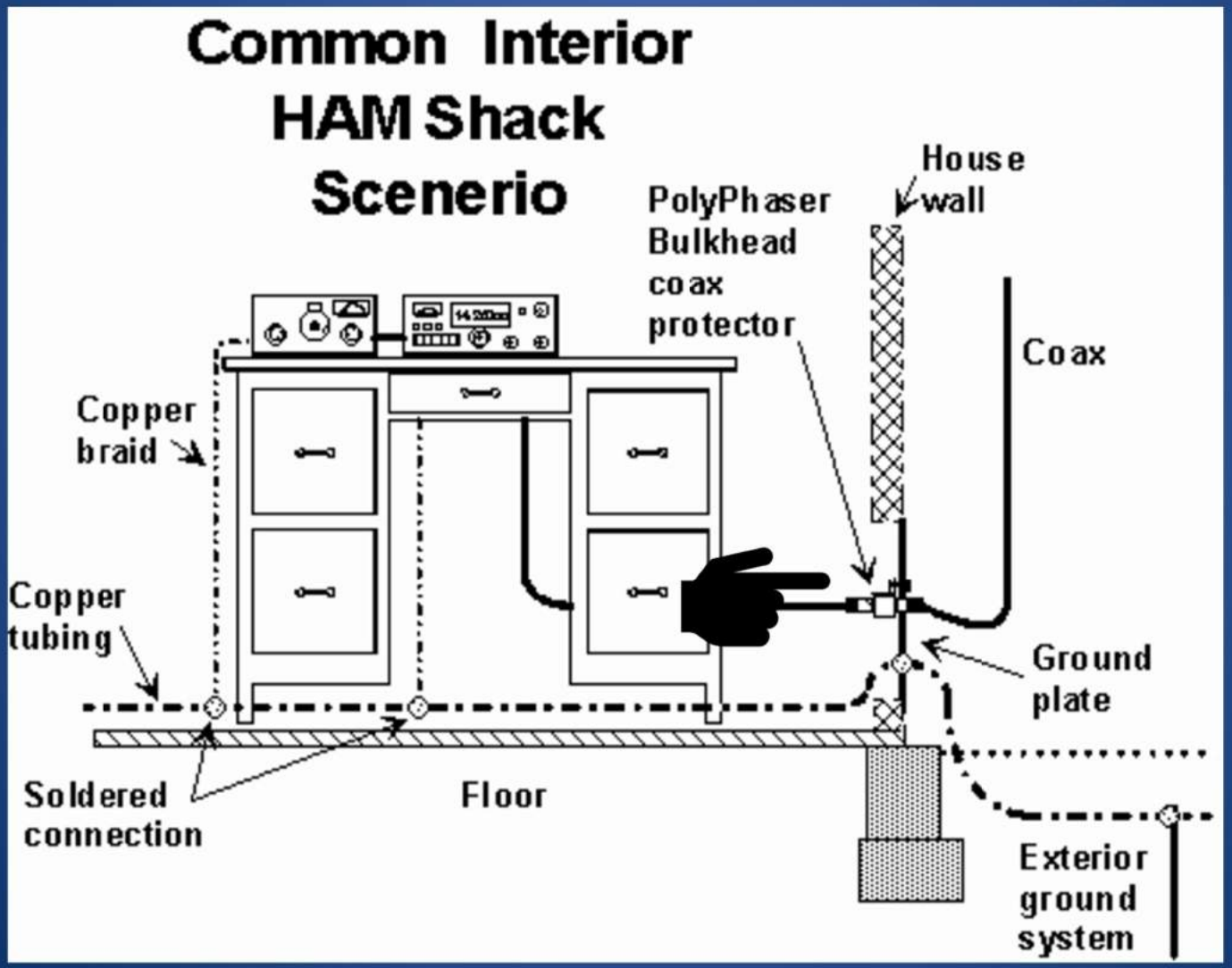
- HF vertical on the ground near house
- HF end fed with matching transformer outside
- now we need an antenna switch, SWR meter, tuner

1. **AC powerline - construct a common bus**
2. **Lightning conductors – tie to ground rod**
3. **RF conductors – keep away from audio**
   -good coax , tight connectors
4. **DC station bus – plan ahead ('x' wall warts?)**
5. **Telephone and LAN wiring (let's do digital)**
   - provide grounding and surge suppression
   for PC , internet and telephone



… #3 HF antennas

- make a solid low Z bus, connect to equipment cabinets
- strive for a single tie point at coax entry to house



ARRL Handbook ch.24

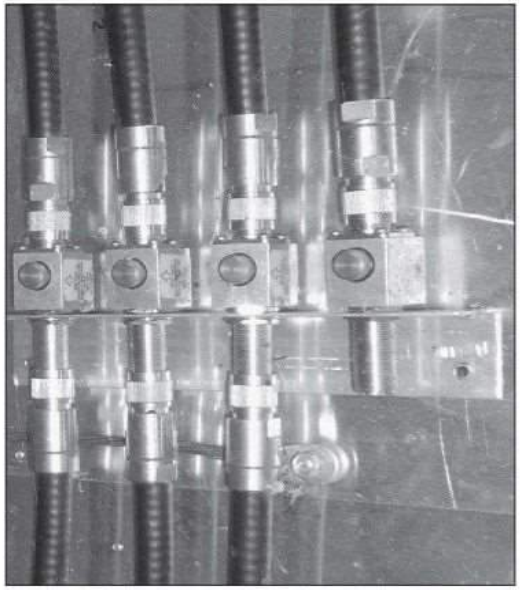


Figure 24.6 — Lightning protectors mounted on a SPGP using an aluminum angle bracket. Some protectors can be mounted directly to panels or as a through-hole using the threaded bulkhead-style connectors. [Ward Silver, NØAX, photo]

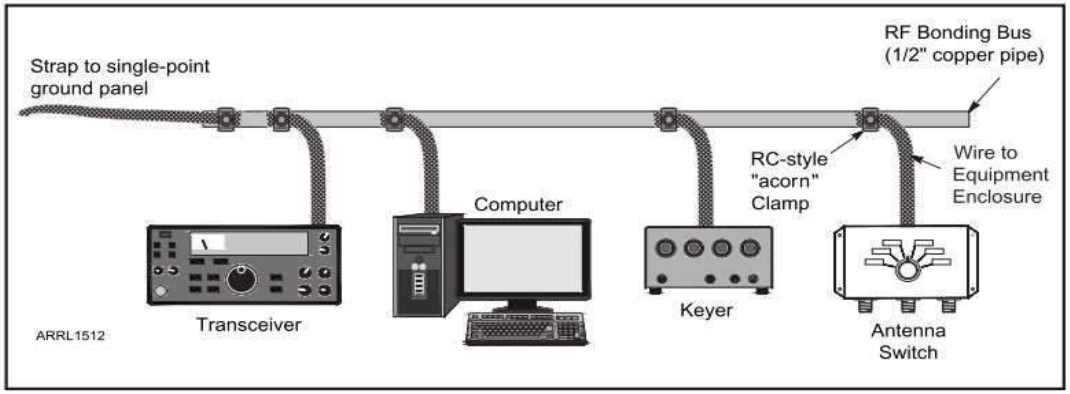
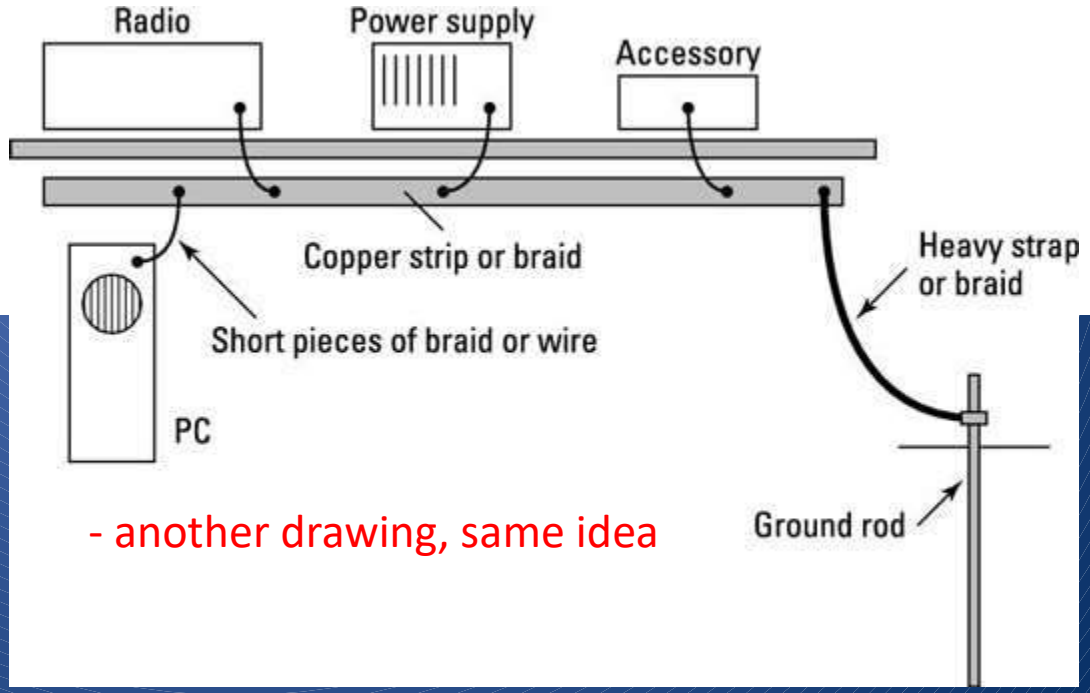


Figure 24.8 — A typical bonding bus for a station with equipment on a table or desk. Connections between the equipment and the bonding bus should be made with heavy wire or strap (#14 AWG is suitable).



- another drawing, same idea

Strive for a single point (common) connection.

- ideally on the outside wall

From ARRL Handbook

- multi outlet power box
- be sure circuit has adequate capacity

serve as an effective bonding bus. Screen or even aluminum foil will work as a ground plane. Have plenty of short jumpers and clip leads to connect the equipment enclosures to whatever common connection you can manage.

Many stations have shelving to hold equipment above a desk or table. **Figure 24.10** shows several possible techniques for adding metal sheet or strap to the shelves and connecting it together. You can use metal sheet, screen, or even surplus PC board material as the ground plane. The important thing is to get some metal under the various pieces of equipment to help the bonding connections work at RF.

24.1.3 Station Power

Power supply design and use is covered in the **Power Sources** chapter, and safety issues and station wiring are covered in the **Safety** chapter. A single 20 A, 120 V circuit will provide sufficient power for all of the radio and computer equipment in almost any single-operator amateur station, including most 500 W power amplifiers. A single 20 A, 240 V circuit will provide sufficient power for two legal limit amplifiers that do not transmit simultaneously. A generous number of 120 V outlets should be provided. The 120 V and 240 V outlets should have their equipment grounds bonded together. This

outlets and 20 A breakers.

Figure 24.11 shows how you can build your own heavy-duty, high-quality power distribution box. Use metal "back boxes" with high-quality outlets and heavy #12 or #14 AWG wiring. Multiple boxes can be mechanically attached together to support as many outlets as needed. If more than one multi-outlet box is used on the same circuit, use rigid EMT or flexible metal BX conduit between them with all of the metalwork solidly assembled and connected to the ground conductor. A heavy switch can be included

made bench. What you use will depend on space, materials at hand and cost. The two most important considerations are height and size of the top. Most commercial desks are about 29 inches above the floor. Computer tables are usually a couple inches lower for a more comfortable keyboard and mouse placement. This is a comfortable height for most adults. Heights much lower or higher than this may cause an awkward operating position.

The dimensions of the top are an important consideration. A deep (36 inches or more)

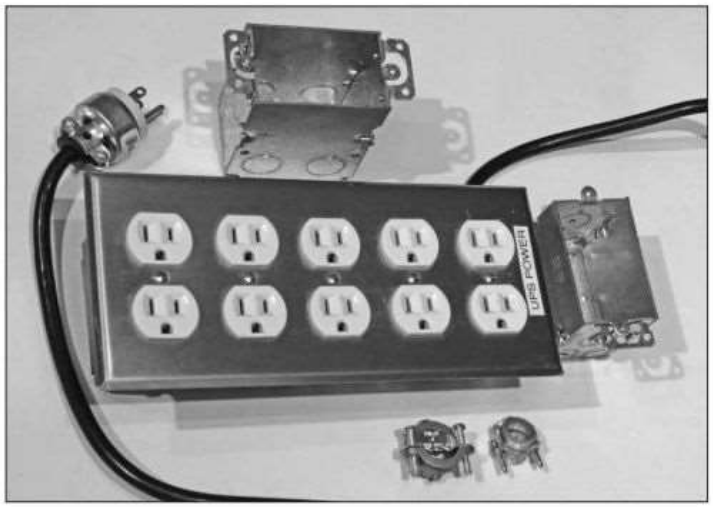


Figure 24.11 — A heavy-duty homemade power distribution box. Several gangable "back boxes" are assembled into a larger box that can hold several duplex outlets. A light switch or GFCI-protected outlet can be included for power control and shock protection. [Jim Brown, K9YC, photo]

#4 I want a linear amplifier!

- a whole new set of concerns and problems
- higher current form AC mains
- higher power in all antenna components
- more RF to get into what it shouldn't
- 5 paths?

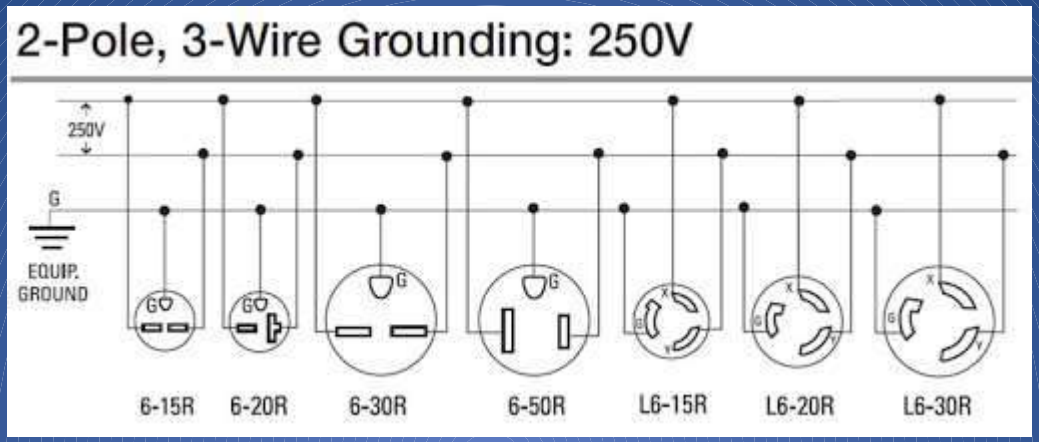
1. **AC powerline**
2. **Lightning conductors**
3. **RF shielding, bonding**
4. **DC station bus**
5. **Telephone and LAN wiring**

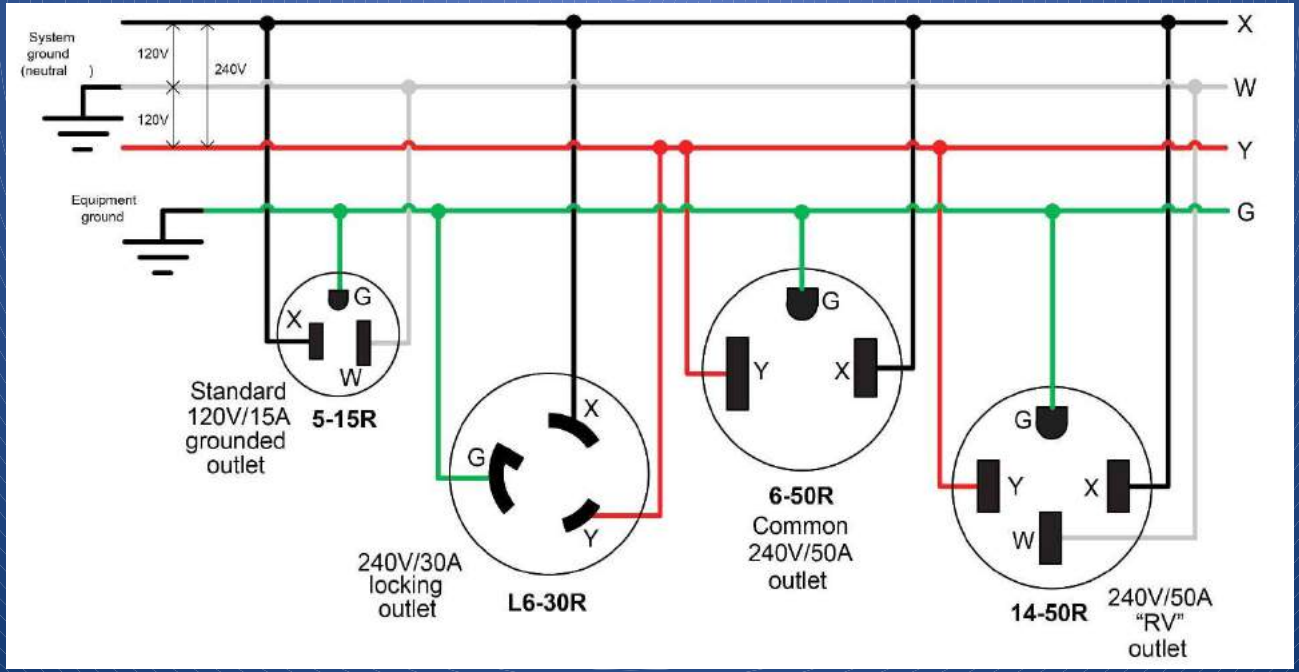
Linear amplifier!

- RF cables as direct as possible
- PTT, perhaps ALC, PC control
- may have separate power supply
- should have SWR, power monitoring

Linear amplifier wiring: -

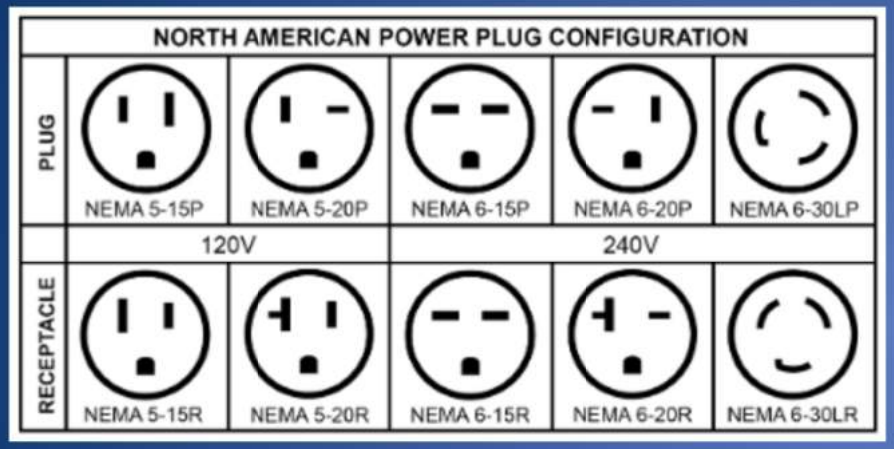
reference slides





Outlets for the amplifier (no neutral)

- check wiring code
- tamper resistant unless twistlock
- use dedicated 240v circuit



NEMA 6-20 - socket is tamper resistant

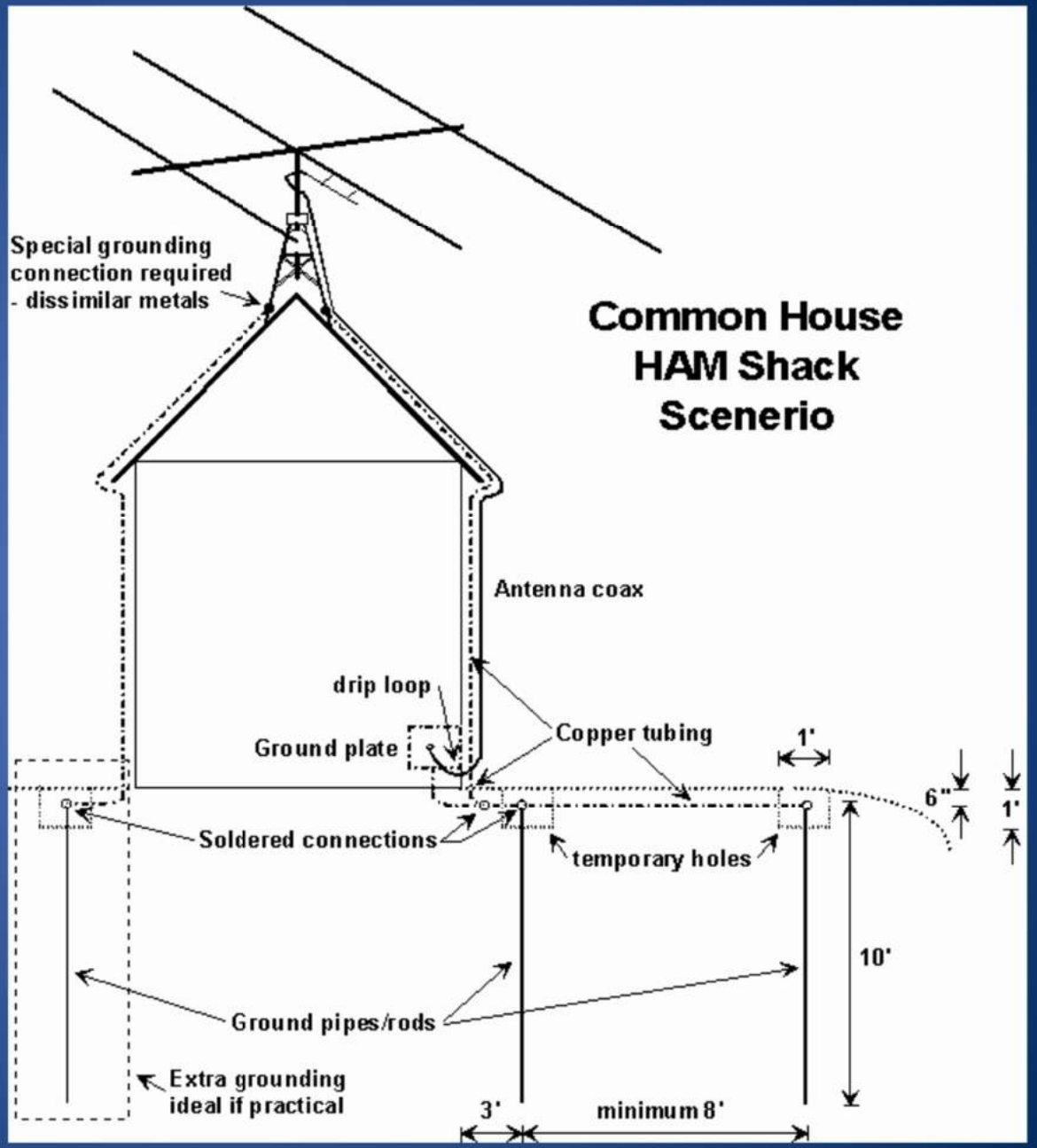
#5 Time for a tower

- this one takes planning and proper installation
- an opportunity for better grounding and lightning protection
- the best SPGP!

1. **AC powerline**
2. **Lightning conductors**
3. **RF conductors, shielding, bonding**
4. **DC station bus**
5. **Telephone and LAN wiring**

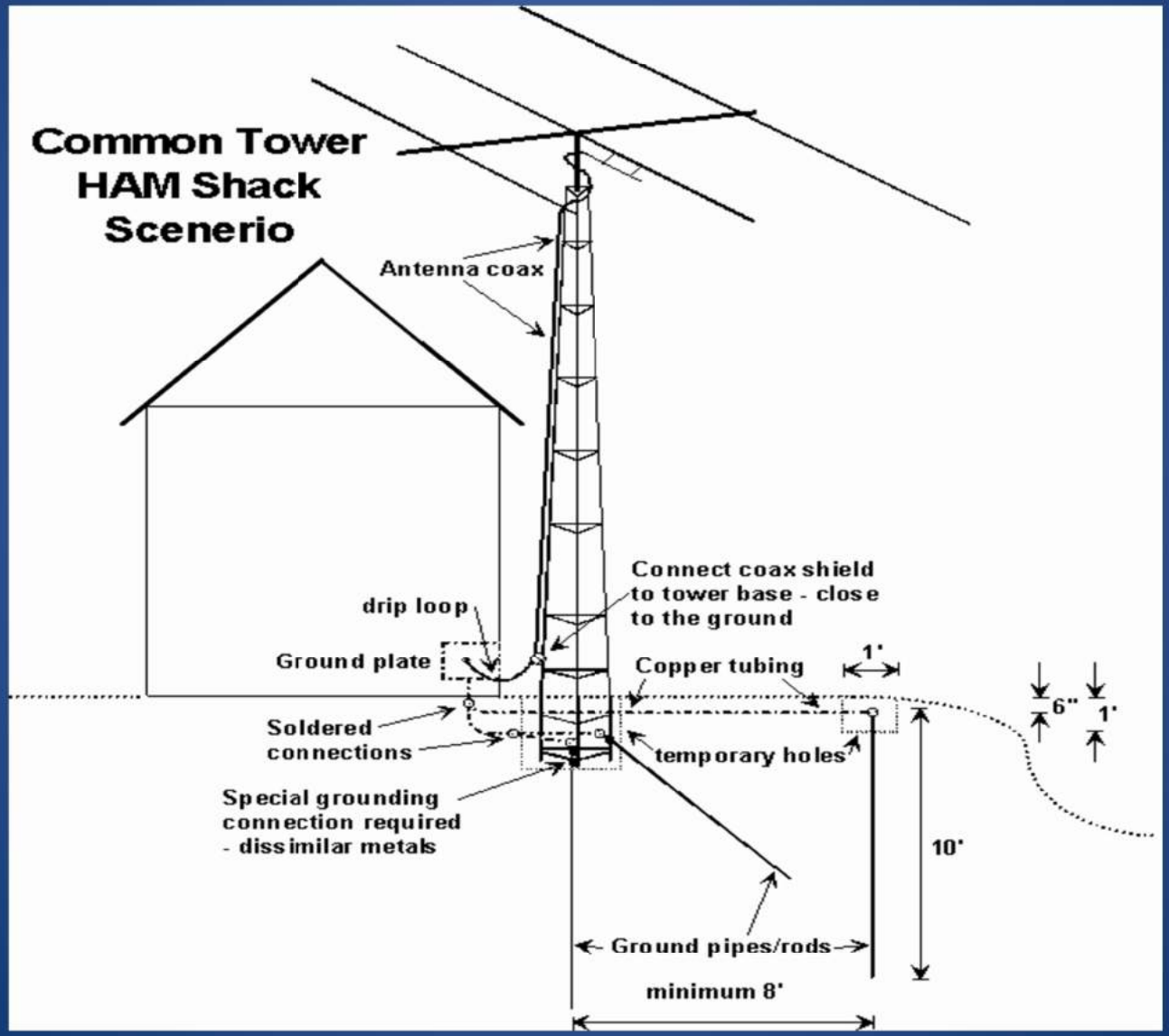
eHam article and N5NJ

- roof installation
- see lightning protection for down conductors
- ground plate is at shack entrance
- all ground rods must be tied together
- ground rods must be bonded to AC service ground
- all ties as direct as possible
- do not connect copper to galvanized or zinc – use a stainless steel barrier
- Thermite welding is the best



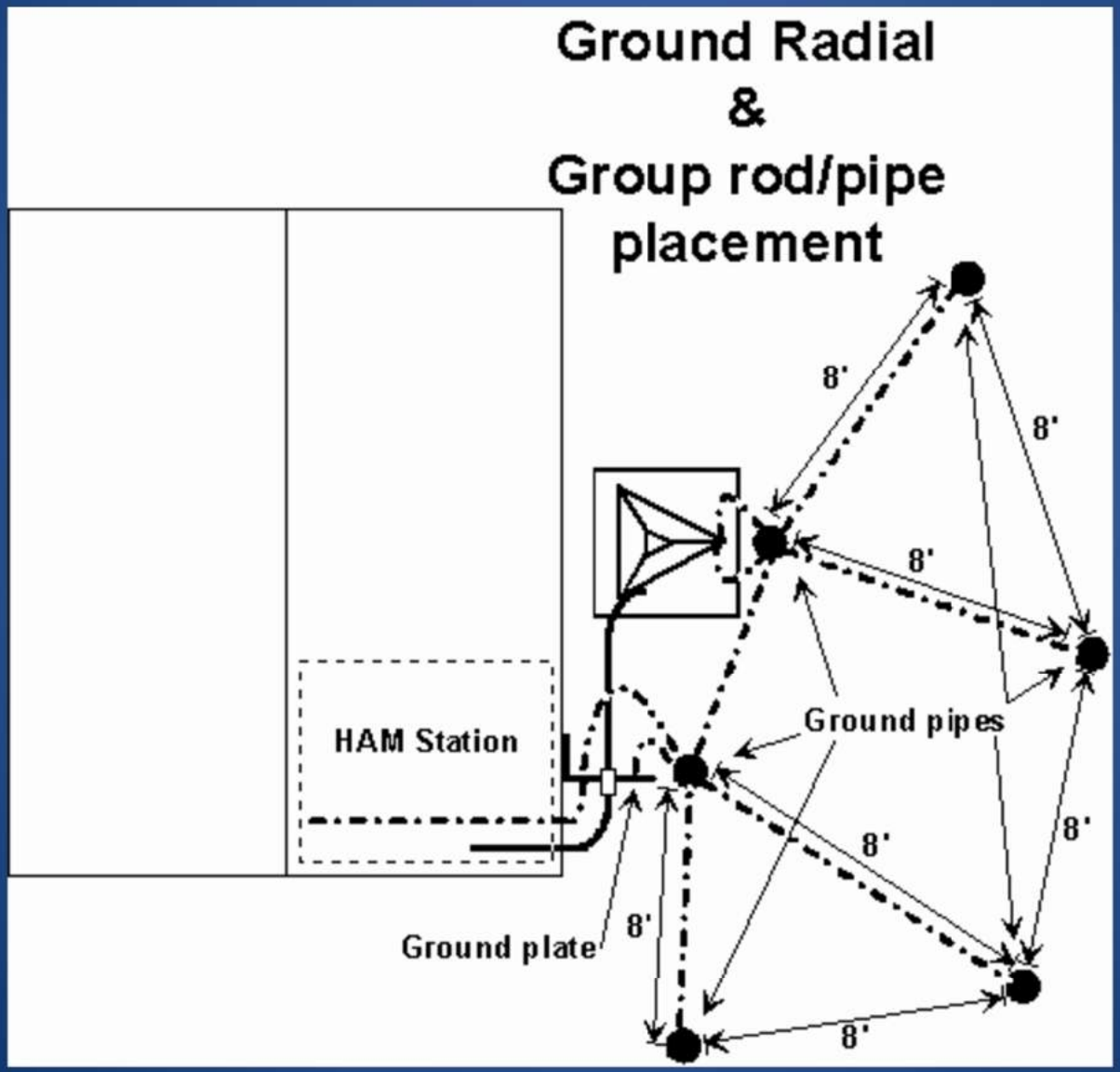
eHam article and N5NJ

tower installation



eHam article and N5NJ

suggested ground rod placement



From ARRL Handbook

- suggested grounding scheme, entire station
- note perimeter tie, bonding to AC service

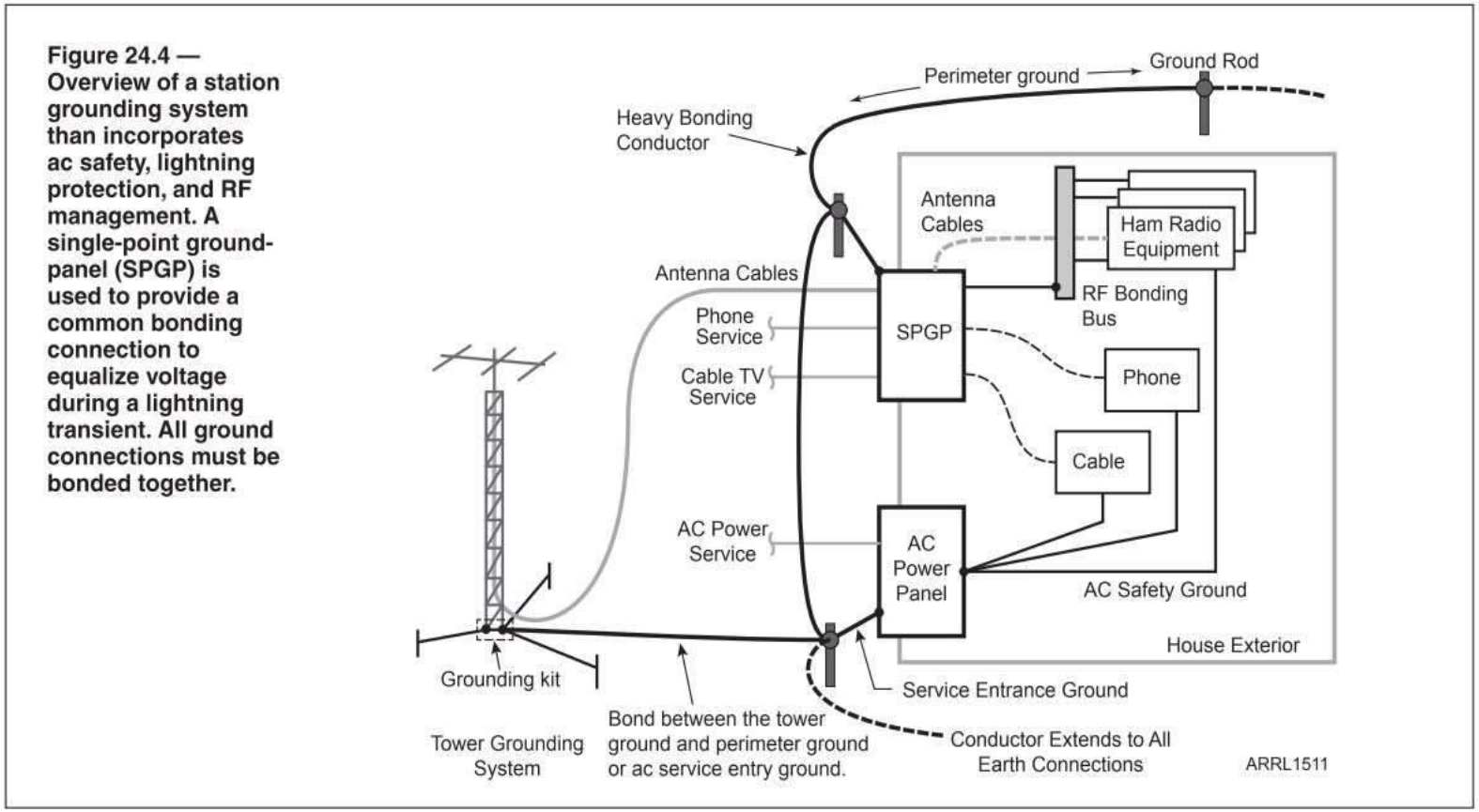


Figure 24.4 — Overview of a station grounding system than incorporates ac safety, lightning protection, and RF management. A single-point ground-panel (SPGP) is used to provide a common bonding connection to equalize voltage during a lightning transient. All ground connections must be bonded together.

Reference slides

Supplier hardware for:

- copper bus bars and straps
- tower grounding
- lightning arrestors

References with web links:

- manufacturer's websites
- articles and presentations
- monumental papers on RFI

and···Motorola R56 STANDARDS AND GUIDELINES FOR COMMUNICATION SITES

This is the very last reference link and though long, is well worth reading.

Chapters 3 and 4 are most relevant to amateur stations. If you could plan your entire house and station form the beginning you could have a commercial level shack!

Chapter 8 has info on RFI.

Don't be discouraged or overwhelmed by the amount of info out there. Start small and apply sound electronic and installation guidelines. There are many ways to build and to solve problems and there will be a need to adjust later.

Get help and advice from professionals or other hams where needed.

73 and best of luck Peter VE6KK

from Georgia Copper:

https://www.gacopper.com/Braid-Strap-Wire-Comparison.html

Wire's main disadvantage is that it is round! It has less surface area than strap or braid, and therefore is less efficient at handling RF currents where a low impedance ground path is needed, such as from a common ground buss or antenna tuner to a ground system. For example, a 4awg wire and a 1.5" x .022" strap have the same cross-sectional area (equivalent circular mils), and they're made from the same amount of copper, but the 1.5" strap has 4.7 times the surface area of the wire!

Braid's greatest advantage is its flexibility

Braid is the conductor of choice where flexibility is required. It is sometimes used for electrically bonding parts of a vehicle, for example an exhaust pipe, door, or hood. At tower sites, braid is good for bonding swinging gates or doors to a ground system - flexibility is a must in such an application. Braid also has some degree of popularity for bonding amateur radio equipment to a common ground buss because of its flexibility. Some people question the effectiveness of braid at radio frequencies. The argument is that each strand of the braid weaves in and out, back and forth across the braid. Currents must either follow that inductive weaving path, or "jump" from strand to strand where strands touch. There are of course many individual strands in parallel, so overall inductance should be low.

Strap's greatest advantage is its surface area

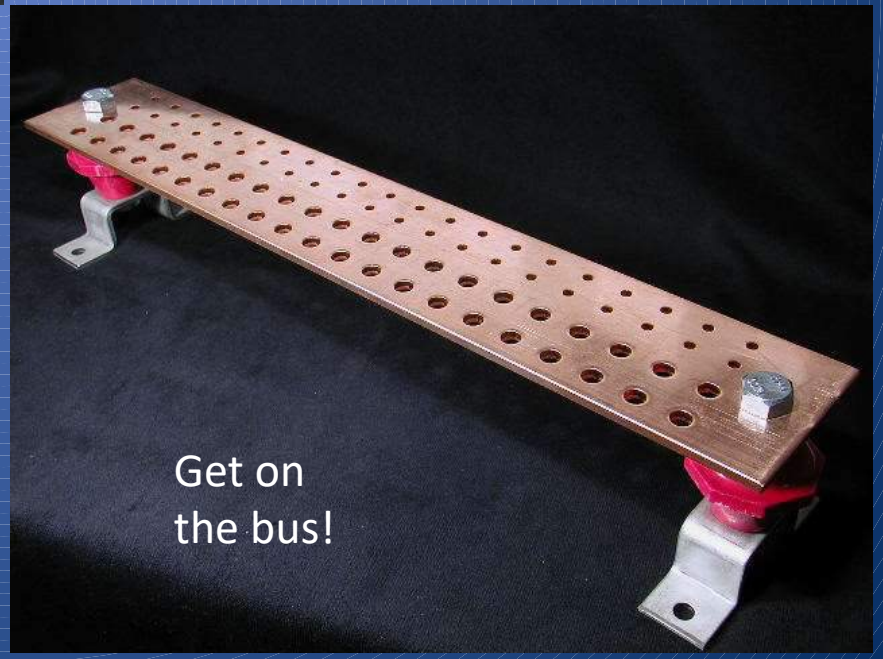
Copper strap (or strip) is the conductor of choice for low impedance RF ground connections. Due to the skin effect, RF currents tend to flow along the outside "skin" of a conductor. Copper strap has a large, smooth surface area to take full advantage of this effect. For decades, copper strap has been widely used in the RF ground systems of broadcast sites.

Lightning - Assuming lightning current is strictly DC, any copper conductor of similar cross-sectional area should conduct lightning current equally well. However, research has shown that lightning is a series of DC pulses with a fast rise time. Conductors with lowest inductive reactance and largest surface area, such as copper strap, should be strongly considered when choosing conductors to handle the fast pulses of lightning current.


WWW.GEORGIACOPPER.COM


Tinned
Copper
Braid
www.GaCopper.com


Copper Strap Jumpers
This photo shows 1" x 6" with 1/4" holes.
www.GeorgiaCopper.com


Get on
the bus!

from K7FP Metal Werks – entry boxes

home products ordering news contact gallery tech

K7FP METALWERKS
CUSTOM TOWER & GROUNDING EQUIPMENT

FRP FIBERGLASS BOXES

Guardian series

GUARDIAN Series™ waterproof boxes

Our FRP fiberglass boxes are perfect for protecting equipment and wiring in harsh environments. The GUARDIAN Series™ boxes are made from fiberglass reinforced polyester with a UL94-5V flame rating, continuous stainless steel hinge, and come with either a removable plastic key or stainless latches (depending on size/model). Boxes are customized to your specific needs, and can be built as a wall mounted entry panel, or a tower/post mounted junction box. All sizes/models are waterproof and have a gasketed lid.

Common, included features of all Guardian Series™ entry panel boxes:

- Made from fiberglass reinforced polyester (FRP) that is extremely durable and non-conductive. Impervious to salt spray.
Light gray finish; can be painted by purchaser before installation.
- Lockable latch (padlocks available below), OR removable plastic key.
- Gasketed lid.
- Copper mounting sheet.
- Grommet holes on bottom for cables; extra holes can be plugged for future use.
- Larger cutouts for conduit in bottom or back also possible. There are **NO** slots in bottom for flat grounding strap in fiberglass boxes.

We also stock and install POLYPHASER, ALPHA DELTA and MORGAN MANUFACTURING surge protectors in our boxes! Arrestors can be pre-installed for a small charge; see "Optional Accessories" below to select this option.

eHam.net online reviews

Installation available

DEFENDER series

Entry panel boxes are designed for the following:

Designed to be mounted on wall of house. Provides convenient outdoor entry point for cables and arrestors.

Large hole in back of box allows cable passage through wall into house. Conduit can be used through wall. Cable flow is from bottom up.

Cables enter box via grommets or larger openings for conduit (or both).

Arrestors are lined up horizontally across box.

Boxes are horizontally oriented.

Can be made in galvanized steel, aluminum, or stainless in multiple gauges. Powdercoated in one of 20 colors.

Available sizes: (Height x Width x Depth)

Small	10x10x4"
Medium	14x14x4"
Large	14x17x4"
Extra large	16x20x4"

INTERCEPTOR series

Junction boxes are designed for the following:

Designed to be mounted on tower, post, or otherwise serves as convenient wiring point between shack and tower. Can also be installed on our concrete mounting fixture.

Cables enter bottom of box via grommets or conduit (or both).

Boxes include copper bridge for rotor/control cables, putting them above coax arrestors to save space.

Arrestors are lined up vertically down box, and cables enter from bottom left, pass through arrestors, and exit bottom right (inverted U configuration for cable flow.)

Boxes are vertically oriented.

Are built in 16 gauge galvanized steel only, and powdercoated in one of 20 colors.

Available sizes: (Height x Width x Depth)

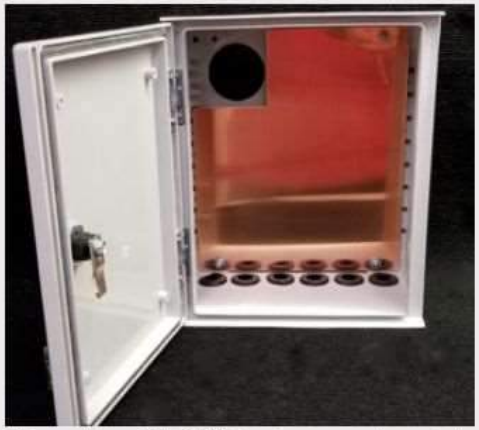
Medium	15x15x6"
Large	18x15x6"
Extra large	21x15x6"

from K7FP Metal Werks

https://www.kf7p.com/KF7P/Fiberglass_boxes.html

Small and Large models come with removable plastic key which prevents lid from being opened.

Medium boxes come with stainless lockable latches. All boxes are customized with grommet holes and/or cutouts for conduit.



This small box (12"x10"x6") is set up as a wall mounted entry panel. 6 grommet holes bottom for cables entering box, and a cut out for 1.5" conduit in the back upper left corner for cables exiting the box.

This medium box (14"x12"x6") is set up as a junction box where all cables enter and exit the bottom through grommets.

Copper sheet is easily removed by unscrewing four stainless nuts.

How to order video, must watch before ordering!

Wow!

Entry panel ready for cables, designed to protect HF and VHF radios and rotator controllers. Box is an XL Entry Panel, powdercoated bronze to match house paint. Photo W2MKM.

Other tower goodies from K7FP Metal Werks

References

- https://electrical-engineering-portal.com/ground-potential-rise-in-your-home
- Safety in Ham Radio – VE6TL 2019 exc. on AC service grounding
- https://www.youtube.com/watch?v=jKdRW6LbWNE&feature=emb_logo
  W6LG video, UFER ground
- https://community.flexradio.com/iscussion/6372675/single-point-ground
- http://kc.flexradio.com/knowledgebasearticle50426.aspx Good but read with scepticism.
- http://www.ifwtech.co.uk/g3sek/in-prac/best-of.htm#earthrods
- https://www.eham.net/article/1603 excellent
- https://www.gacopper.com/Braid-Strap-Wire-Comparison.html
  See also home page
- Coax lightning arrestors VA7JW super stuff at end
- https://www.dropbox.com/s/kffp92esffo3zy5/How%20to%20Build%20a%20Quiet%20Station%20V2.pdf?dl=0

- https://en.wikipedia.org/wiki/Ufer ground inside concrete!

References, cont…

- http://leckemby.net/aj0ml/notionalgroundingsystem.html-good summary of integrated grounding system
- https://www.w8ji.com/second_floor_grounding.htm
- http://www.ad5x.com/images/Presentations/Lightning.pdf
  See his excellent presentation on Lightning
  and many other articles, reviews and presentations!
- https://www.eham.net/reviews/view-category?id=17&sort=-activeReviewsCount
  Reviews on lightning and surge supressors
- https://www.arraysolutions.com/surge-and-rf-protection/as-8sp
- BICSI Grounding and Bonding paper
- QST- Lightning Protection- Chusid-Morgantion

- https://www.blm.gov/sites/blm.gov/files/Lands_ROW_Motorola_R56_2005_manual.pdf
  STANDARDS AND GUIDELINES FOR COMMUNICATION SITES

Motorola R56 document (link)

"Standards and Guidelines for Communication Sites"

2.12.2.1 POINT OF ENTRY FOR RF TRANSMISSION LINES

Reducing the height at which the RF transmission lines (coaxial cables) leave the tower and enter the building can reduce the susceptibility of a communications site to damage from lightning (Figure 2-1).

The reduction in height reduces the voltage on the RF transmission lines before they enter the facility. A suggested best practice is for the coaxial cables to enter the facility at a maximum height of 610 mm (2ft.) above the facility floor

(United States National Weather Service Manual 30-4106-2004, "Lighting Protection, Grounding, Bonding, Shielding, and Surge Protection Requirements").

Motorola R56 document (link)

"Standards and Guidelines for Communication Sites"

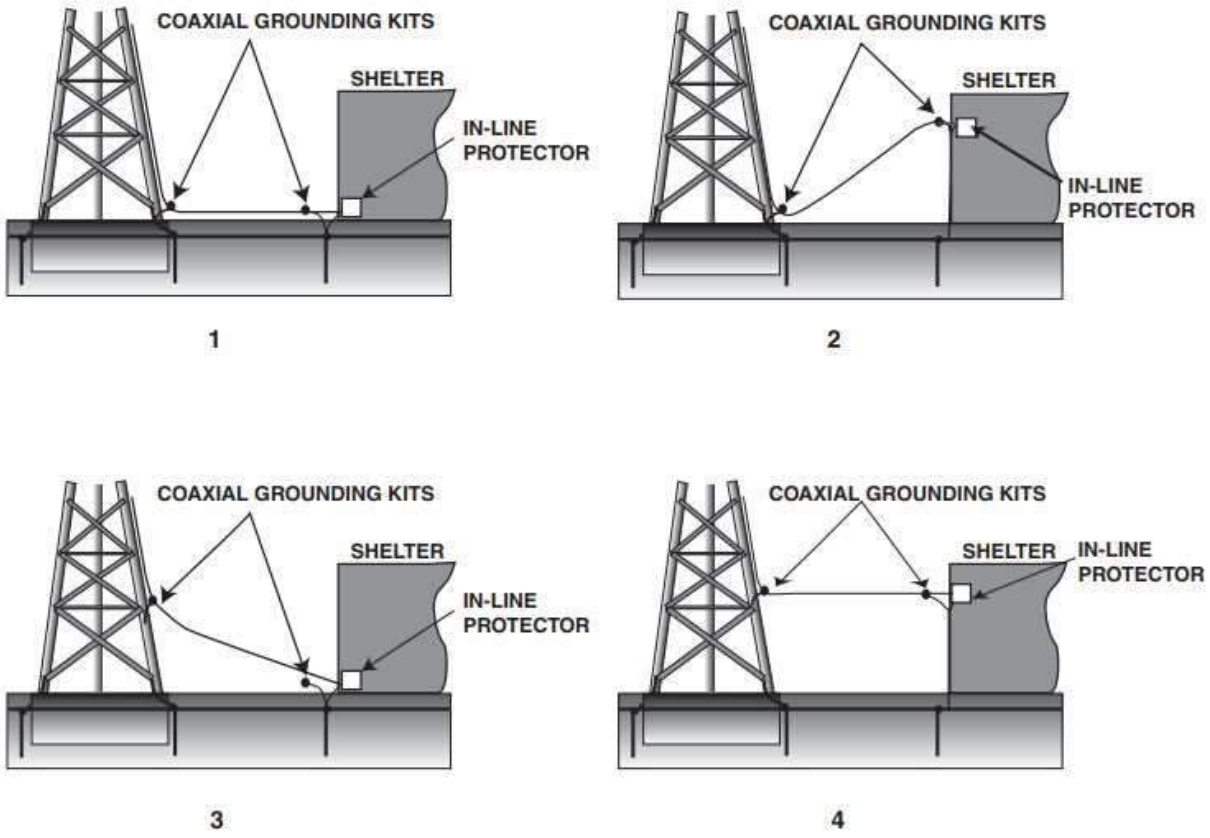


FIGURE 2-1 TRANSMISSION LINE ENTRY POINTS (IN ORDER OF PREFERENCE)

Motorola R56 document (link)

"Standards and Guidelines for Communication Sites"

2.12.2.2 Distance Between Tower and Building

Increasing the distance between the tower and building may reduce the susceptibility of a communications site to damage from lightning. Increasing the distance between the tower and building has the following benefits:

• It decreases the magnetic field associated with lightning that is coupled into the building. The amount of magnetic field coupled into the building decreases by the square of the distance. For example, the magnetic field coupled into a building would decrease by a factor of nine (9) if the distance between the tower and building is increased by a factor of three (3).

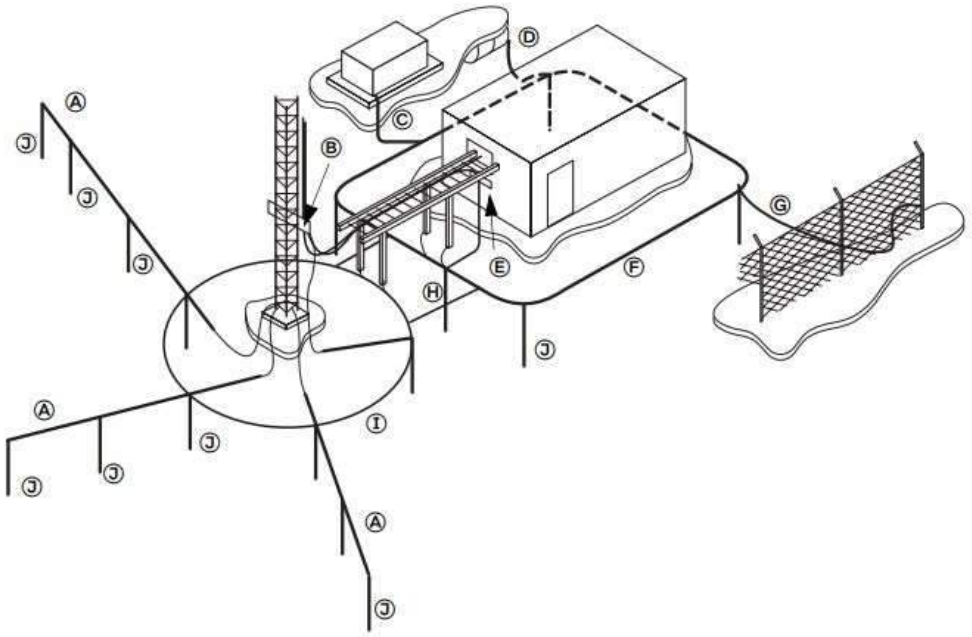
• It reduces the amount of energy that reaches the building via the RF transmission lines. This is because of the increase in inductance of the longer transmission lines.

• It reduces the amount of lightning energy that is propagated through the earth from the tower grounding (earthing) electrode system to the building grounding electrode system.

• Nine metres (30 feet) is considered a good compromise between protection level benefits and the length added to RF transmission line.

Motorola R56 document (link)

"Standards and Guidelines for Communication Sites"



A: Grounding Radials
B. Tower Ground Bus Bar and Down Conductor
C. Generator Grounding Conductor
D. Buried Fuel Tank Grounding Conductor
E. External Ground Bus Bar
F. Shelter Ground Ring
G. Fence Grounding Conductor
H. Ground Ring Bonding Conductors (2 minimum)
I. Tower Ground Ring
J. Earthing Electrodes (Ground Rods)

FIGURE 4-4 TYPICAL EXTERNAL GROUNDING ELECTRODE SYSTEM

Motorola R56 document (link)

"Standards and Guidelines for Communication Sites"

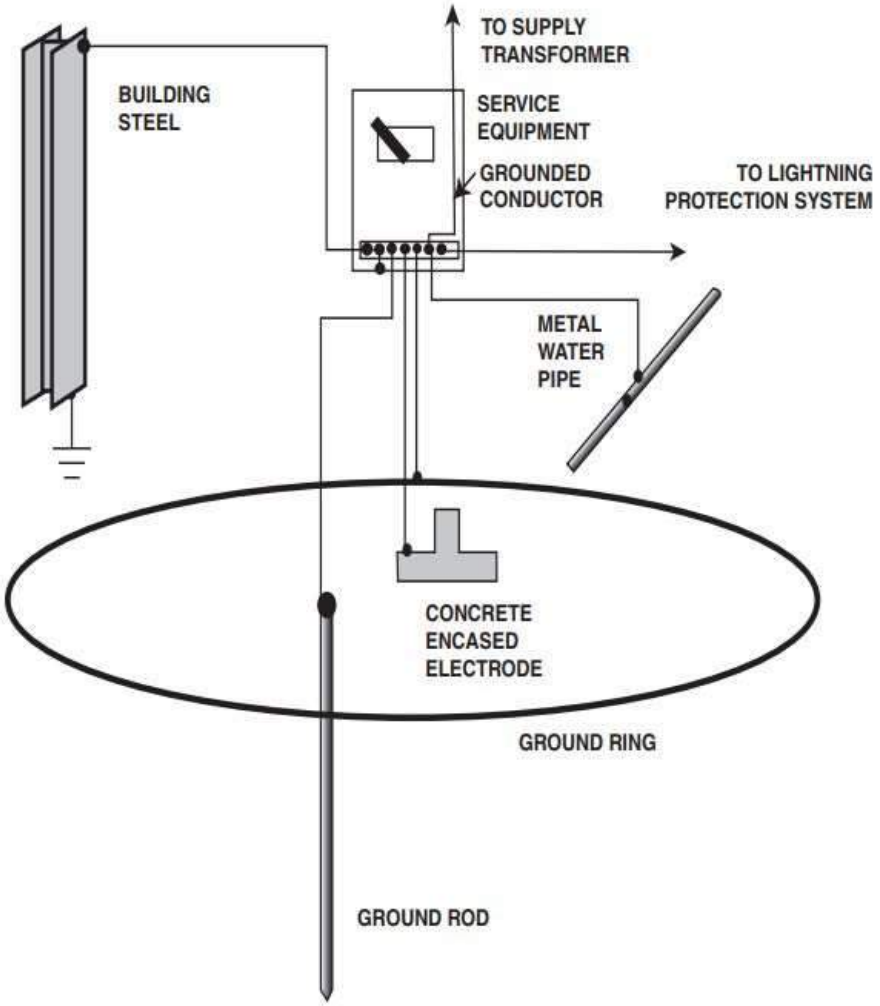


FIGURE 4-3 COMMON GROUNDING EXAMPLE

Motorola R56 document (link)

"Standards and Guidelines for Communication Sites"

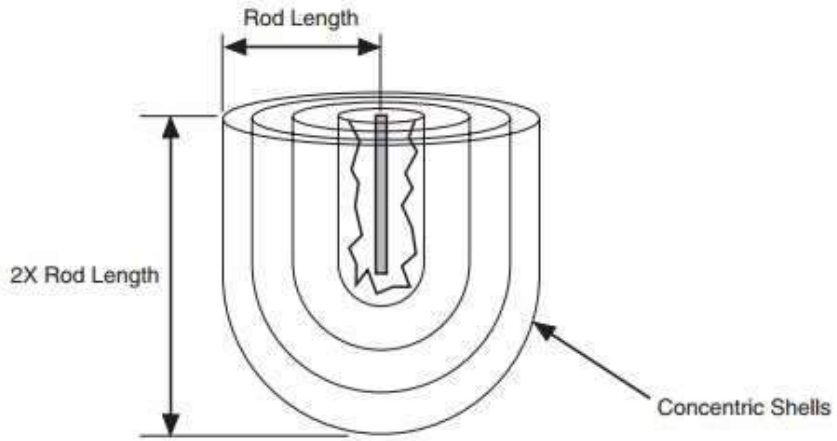


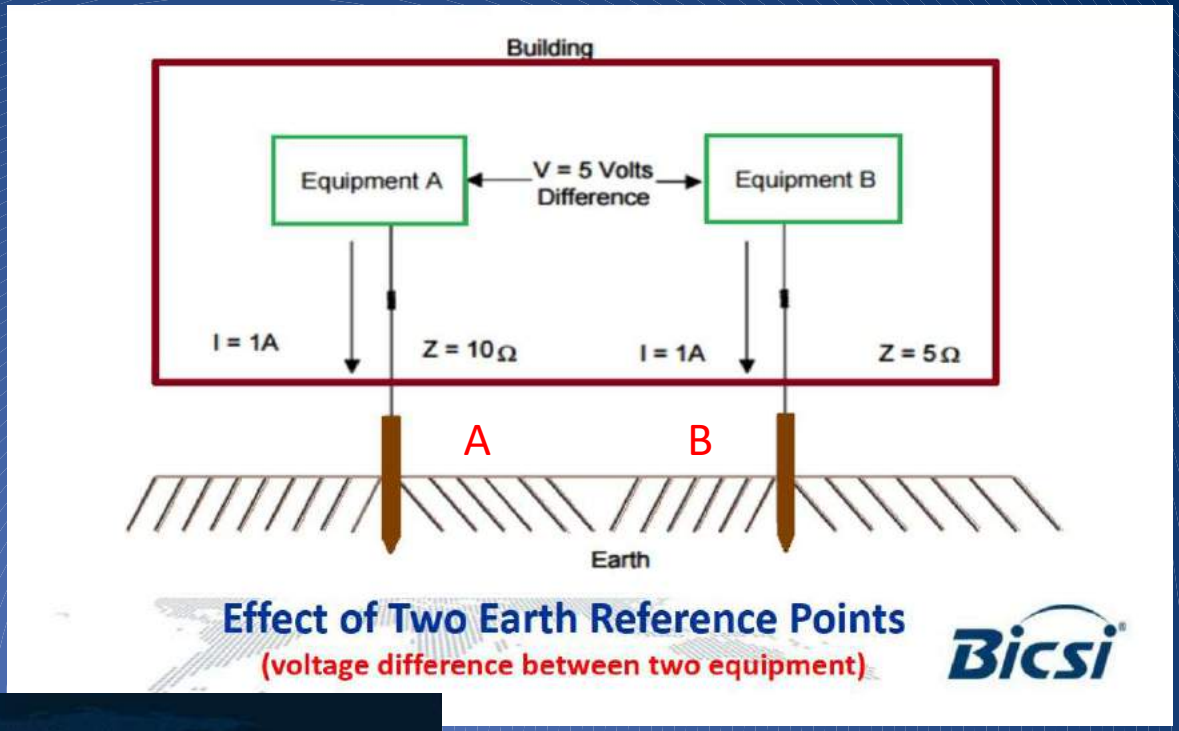
FIGURE 4-5 GROUNDING ELECTRODE SPHERE OF INFLUENCE

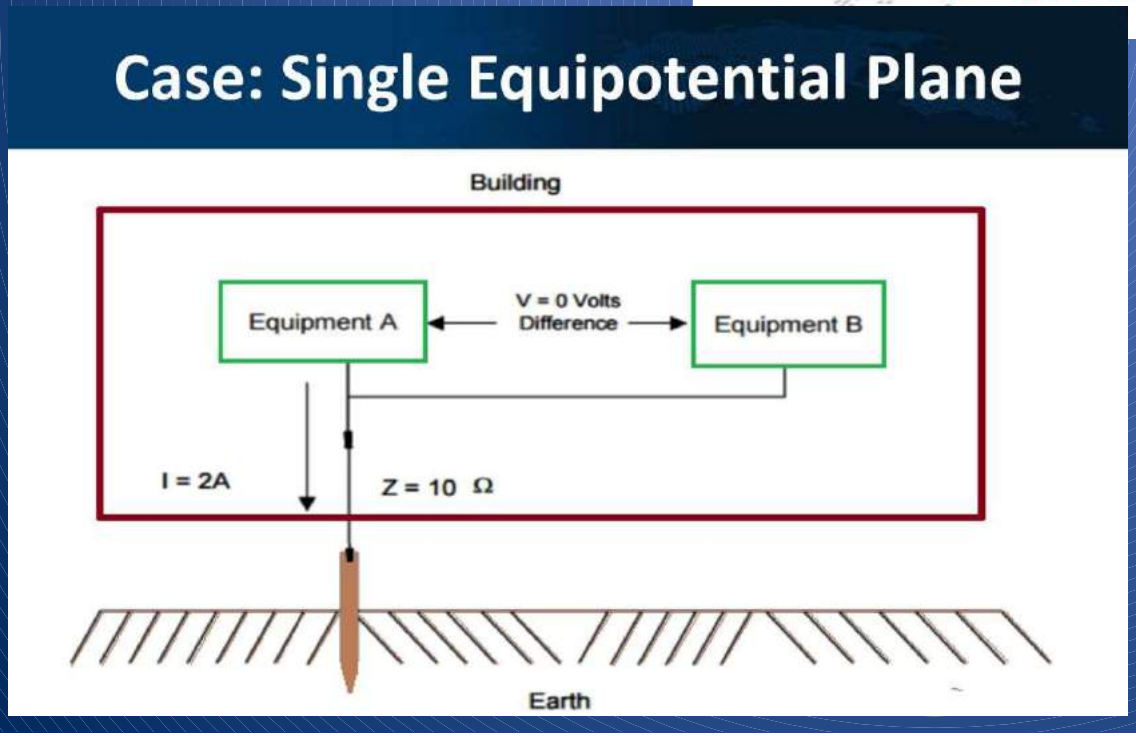
The effect of the concentric shells is that it takes a finite amount of earth for a ground rod to fully realize its resistance value. This finite amount of earth is commonly known as the ground rod's sphere of influence. The sphere of influence for a ground rod is commonly thought of to be a radius around the ground rod equal to its length; the ground rod achieves approximately 94% of its resistance value at this radius (100% is achieved at approximately 2.5 times the rod length) (IEEE STD 142-1991, section 4.1). See Figure 4-5.

[BICSI Grounding and Bonding paper]

(click for link)

What if there were 10 Ohms reactive A to B and a 10 kA strike? => 100kV !





Monumental papers on RX noise reduction

Common-Mode Chokes by Chuck Counselman, W1HIS(link)

A Ham's Guide to RFI, Ferrites, Baluns, and Audio Interfacing
– Jim Brown K9YC (link)
Build Contesting Scores by Killing Receive Noise - Jim Brown K9YC (link)

Killing Receive Noise - Part 1 – Jim Brown (link)
Killing Receive Noise - Part 2– Jim Brown (link)

Pages open for presentation

- KE0OG video (fair)
- 2 eham pages – article, reviews on supressors
- 2 flex pages (some questionable comments)
- (Luxurion - Lightning protection)
- polyphaser/ICE. Metalwerks, DX Engineering, Amazon etc.
- VA7JW presentation coax supressors
- AD5X presentation – pdf
- How to build a quiet station KY6LA – pdf
- Motorola R56 - pdf