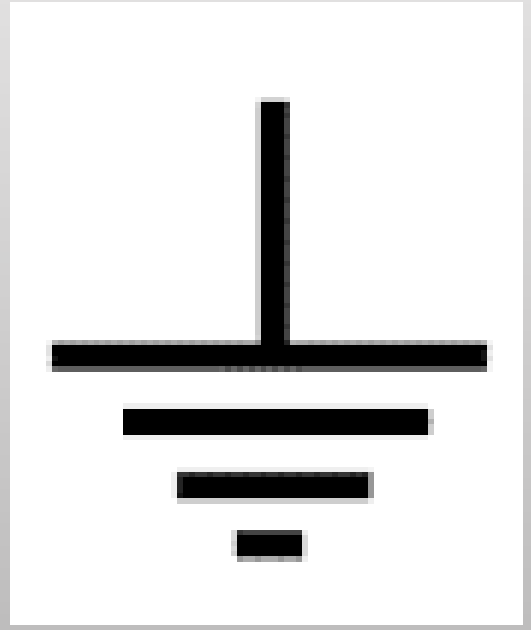
Amateur Radio Station Grounding Common Practice

National Electric Code and Local Code Grounding Requirements

How many Ground Rods?

SURGE PROTECTORS



Why Grounding is Important?

1) Cause operation of overcurrent protection.
2) Zero reference for entire building electric system
3) Equalize all potential differences.

Is there a Sure Method of Lightning Protection? No.

Dave, N9KMY

Three Types of Grounds

1. **Electrical Power Safety Ground** – A Single Common Ground at the Main Disconnect, Bonded to the Earth and the Electrical Neutral. Ground is extended to Every Power Outlet/Device, the **GREEN Wire**
2. **RF Signal Common Mode Ground** – Reduce Common Mode Interference such as RFI via short Connections (< ¼ Wavelength)
3. **Lightning Protection Ground** – Short Circuit Atmospheric Discharges (Lightning) to the Earth

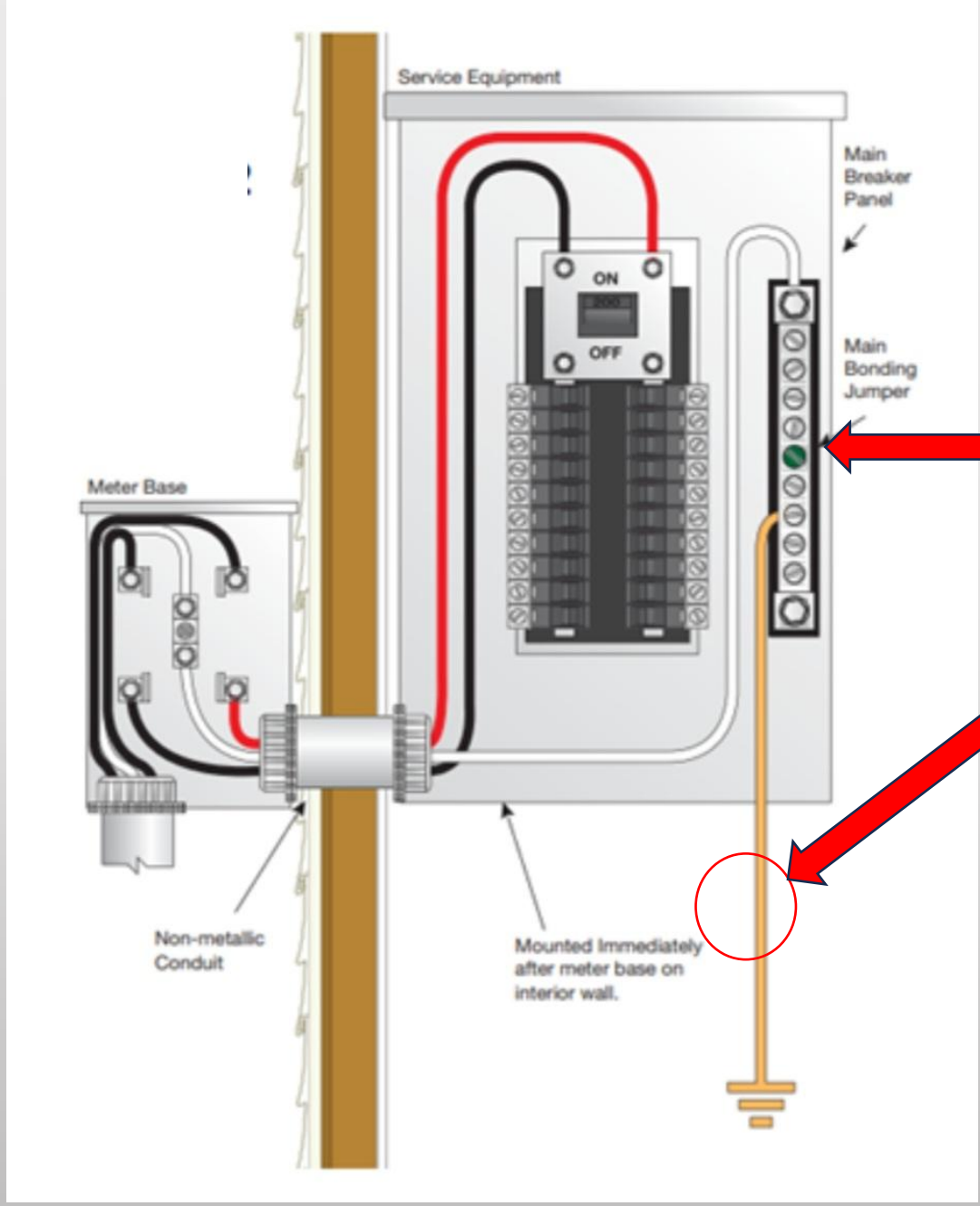
ALL GROUNDS MUST BE BONDED per National Electrical Code
[Bonding means to be electrically connected thus equal-potential.]

The Basics: Grounding – Earthing - Bonding

1. A ground conductor Shall NEVER Carry Operational Current	**2. Size ground/bonding conductors to carry expected current**	**3. A structure shall have only ONE Ground Common Point (at the Main Disconnect)**	**4. The earth is the LOW-VOLTAGE Reference Point for All Measurements**
Safety Ground: Nat. Electrical Code only requires 25Ω or less to the earth	**RF Ground: 5-10Ω to the earth per Communications Standards, ie., IEEE**	**Lightning Ground: Sufficient mass to reduce discharge current losses**	**Bond everything to Equalize Voltages of all metallic devices**

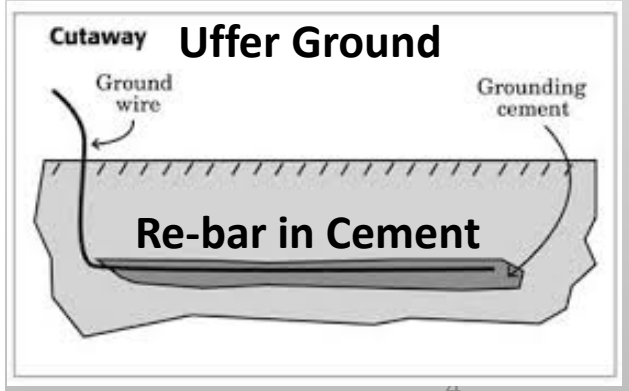
What is Earthing? A direct, low-resistance, physical connection to the conductive mass of the Earth, serving as a zero-volt reference point. This acts as a safety mechanism to prevent electric shocks by discharging currents, such as lightning, or faults, into the earth. {E&S Grounding Solutions}

Single Point Ground at Electrical Disconnect per the NEC **Safety!**



Per NEC 250.30, 250.52: The Ground Bus and Neutral Bus shall be bonded only at one point in a structure - here.

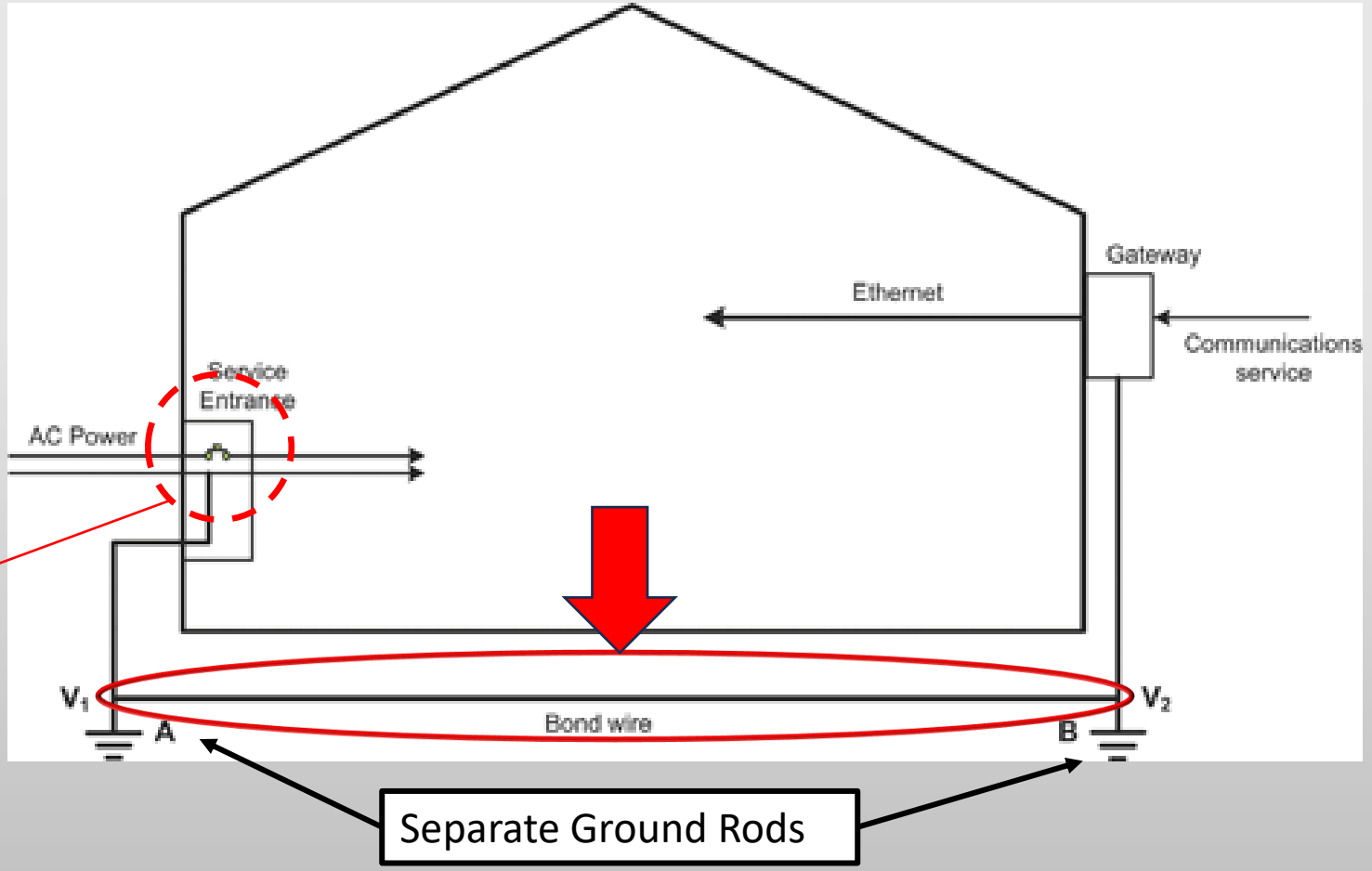
Location to make station bonding connection.



RULE #1: BONDING

Bonding maintains electrical parts at close to the same voltage level reducing potential of arcing/fire.

NEC (NFPA 70) and National Lightning Protection Code (NFPA 780) Bonding Jumper is Absolutely Essential

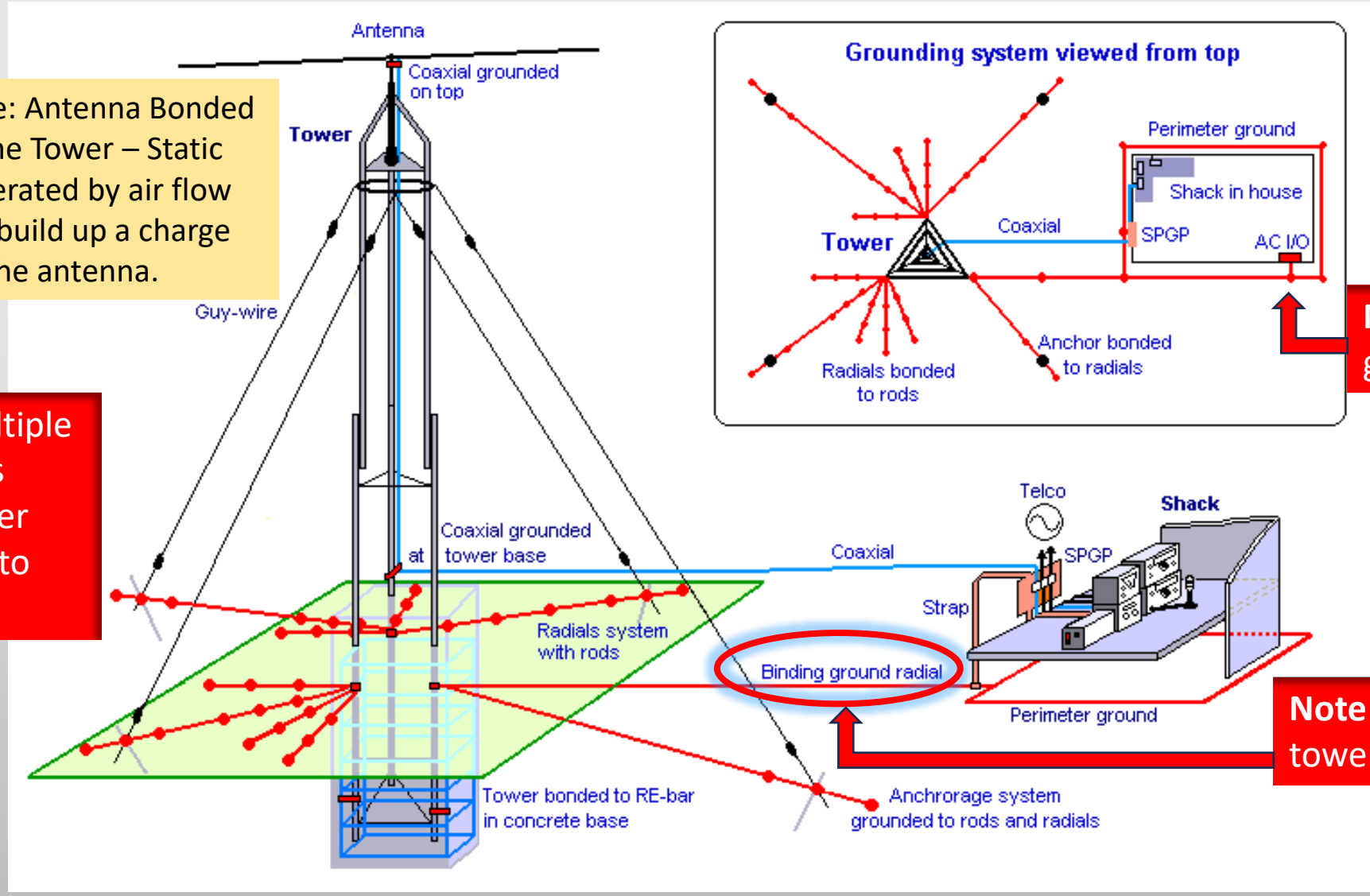


The only place Ground and Neutral are Bonded!

The National Electrical Code: AC Grounding is "Touch Safety"

RF Grounding – Polycom Recommendation

Note: Antenna Bonded to the Tower – Static generated by air flow can build up a charge on the antenna.



Note 1: Multiple ground rods used to lower impedance to the earth!

Note 2:AC ground bond.

Note 3: Shack to tower ground bond.

Ground the Tower, Rebar and Coax Runs

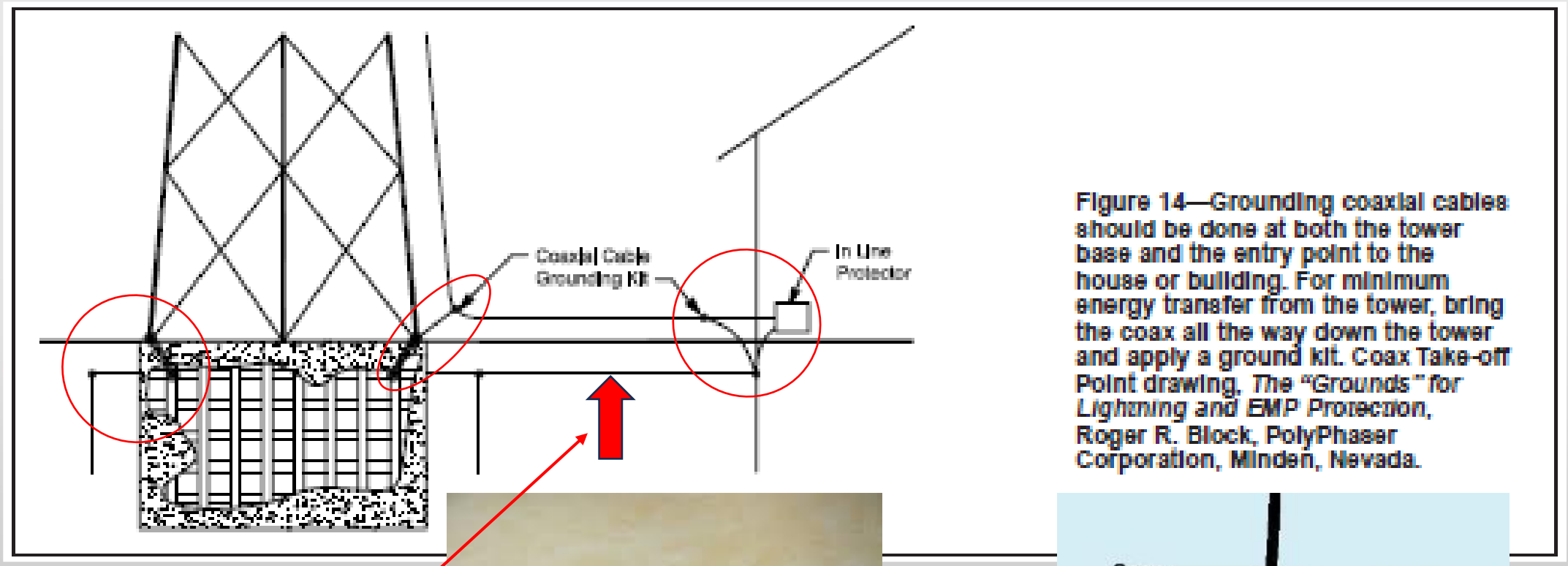
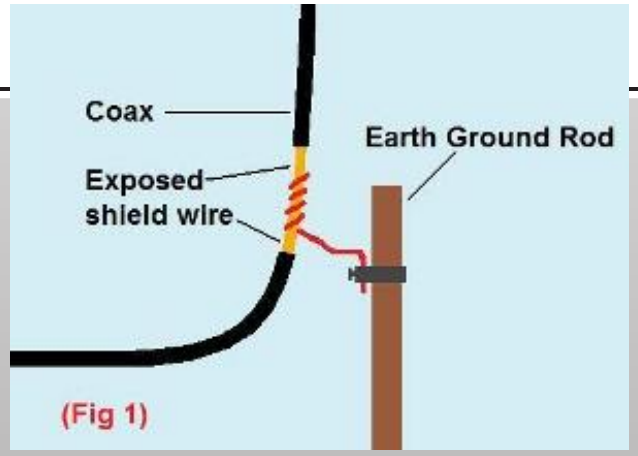
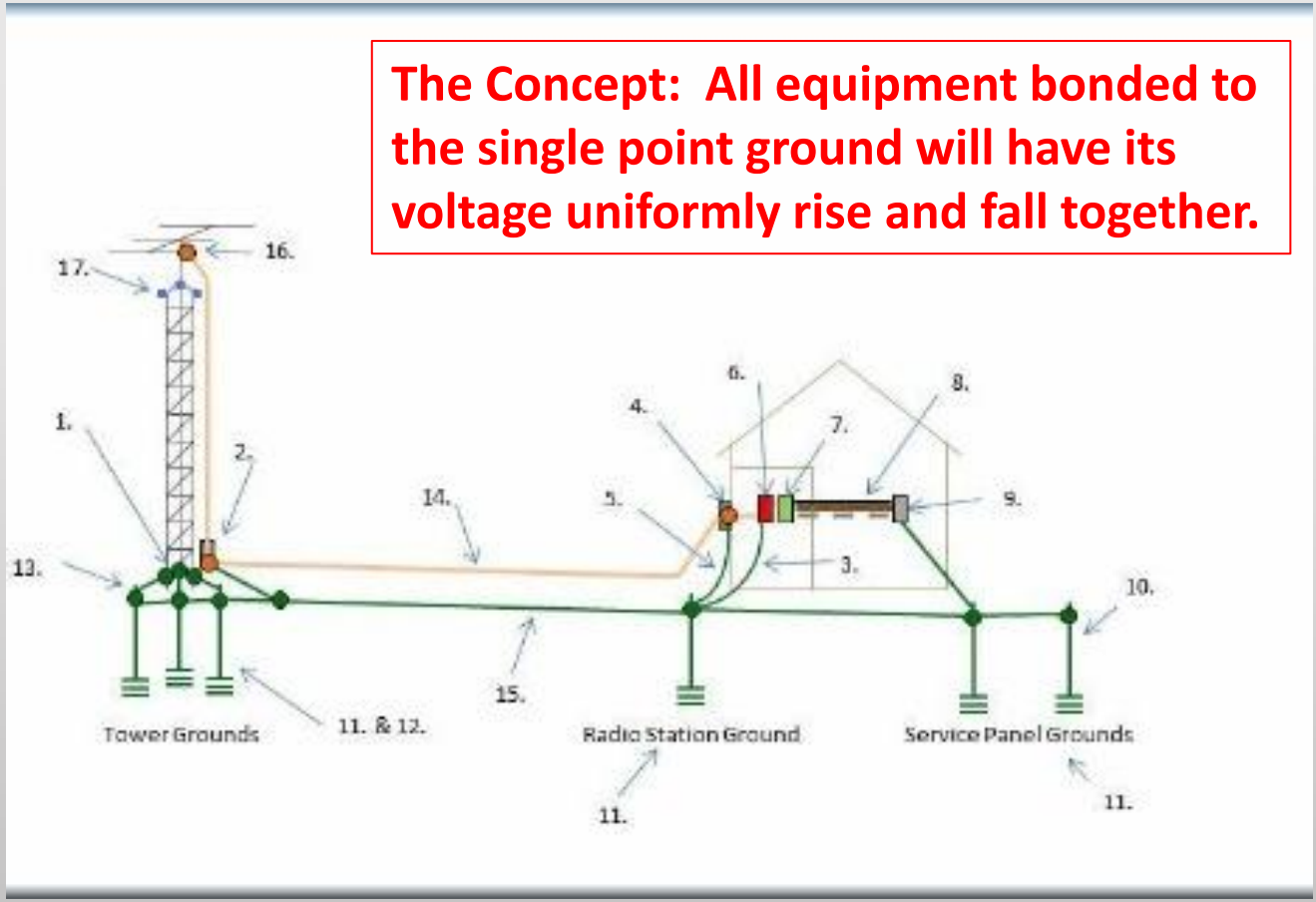


Figure 14—Grounding coaxial cables should be done at both the tower base and the entry point to the house or building. For minimum energy transfer from the tower, bring the coax all the way down the tower and apply a ground kit. Coax Take-off Point drawing, *The "Grounds" for Lightning and EMP Protection*, Roger R. Block, PolyPhaser Corporation, Minden, Nevada.

Remember the all-important bonding!

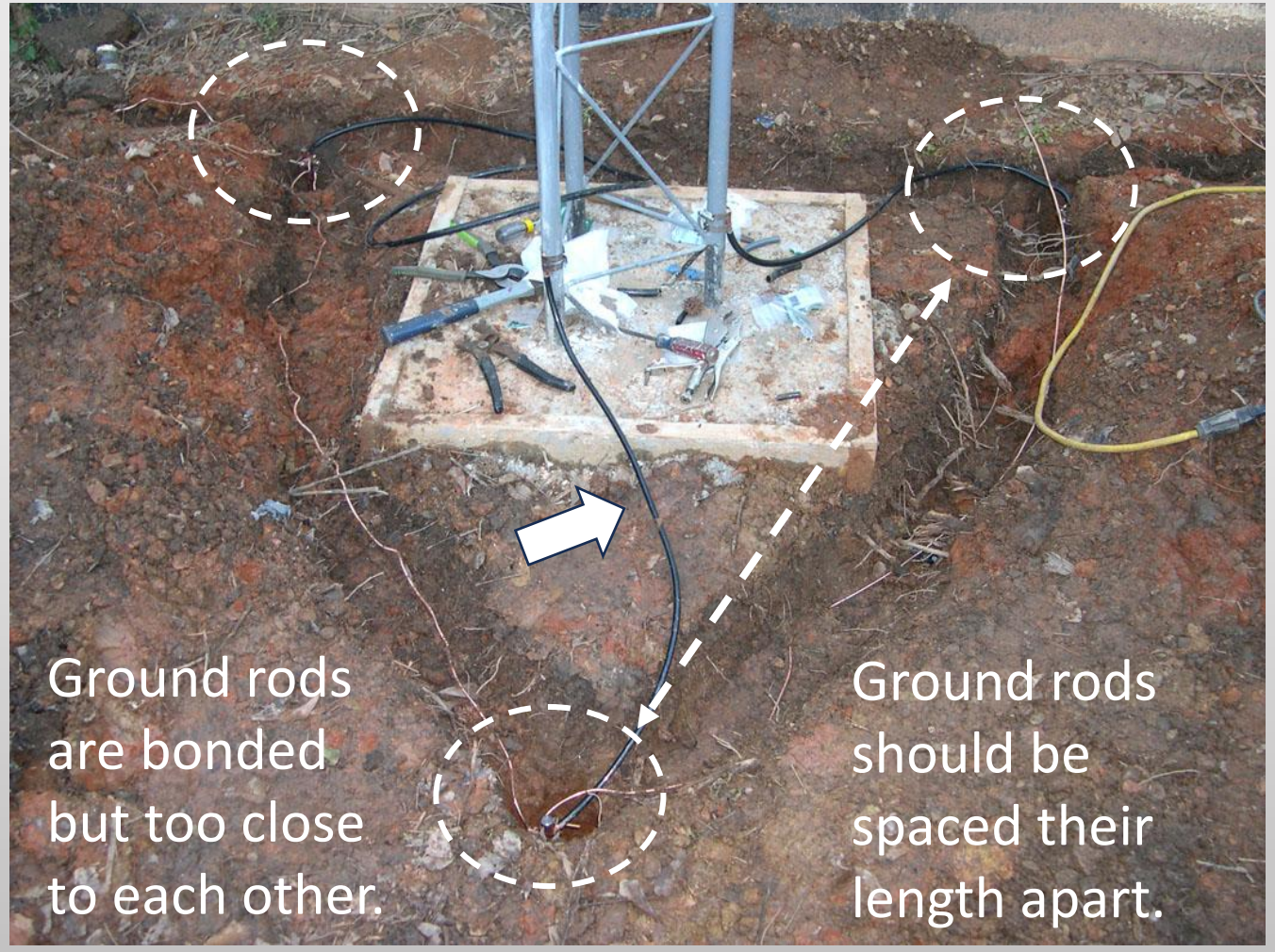


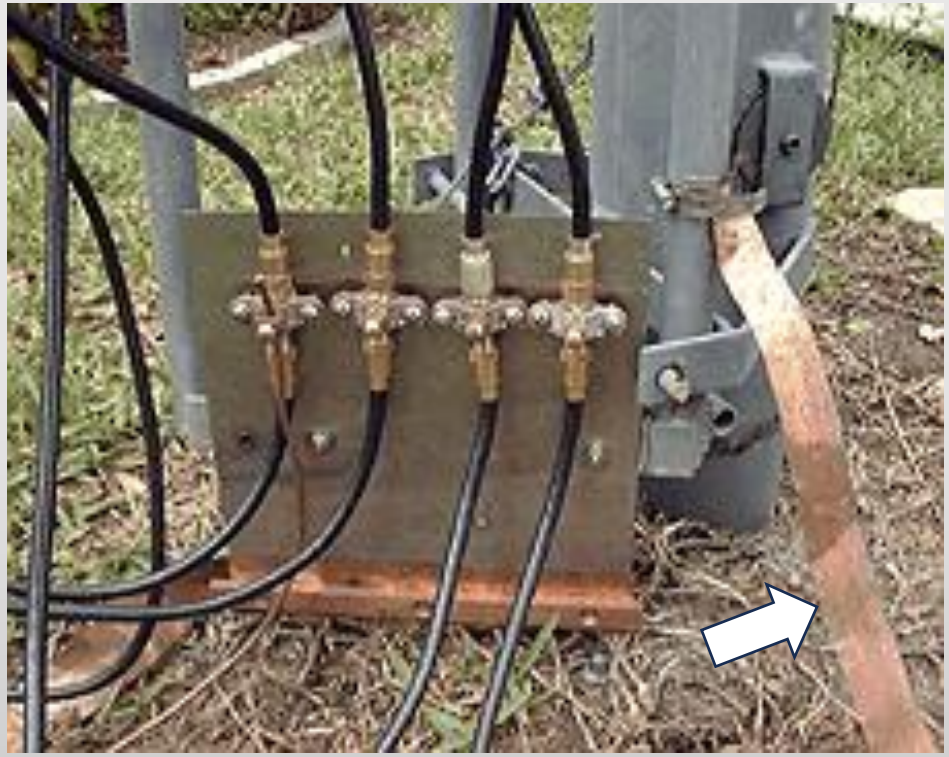
Overview Summary of Bonding Everything



- Tower Ground System (1, 11-13)
- Antenna Coax Bonded to Tower (2&16)
- Tower Ground Bonded to External Shack Ground (15): Note: Earth only is not acceptable unless far enough away!
- Shack Single Point Ground (6)
- Shack Single Point Ground Bonded to Electrical System (8)
- Electrical Outlet for Shack is Bonded (7) to Shack Single Point Ground (6)
- The Main Electric Panel (9)
- Ground Rods (11): Note how many!

Typical Tower Ground Array & Twr. Base Coax





The grounding near the tower provides a place for the common mode noise current to go, thus “short circuiting,” where it cannot couple significantly to the receiver. KV5R

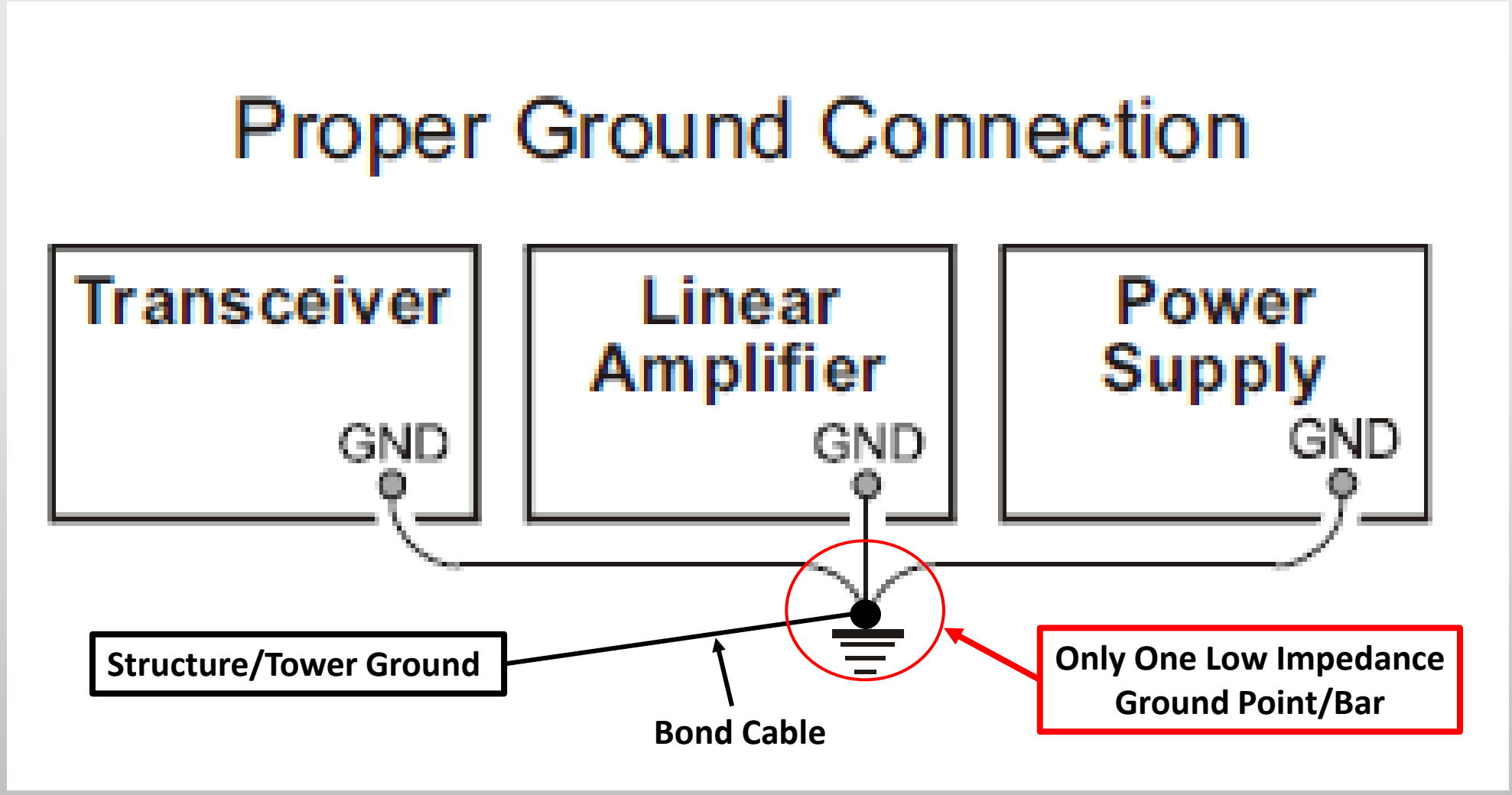
Common Grounding Mistakes

- **Not** Enough Ground Rods (Electrodes)
- **No** Surge Protection at the Base of the Tower/Mast
- Site Grounds **not** being Bonded together
- Ground Rods **too** Close to one another to be effective
- Ground Wire **too** Small
- Bends of Wire **too tight**
- **Connecting** with dis-similar Metals
- **No** Single Point Ground for the Shack

Remember it is all about risk! Pay now or pay later?

Disclaimer: You are on your own to do the best job possible to protect your amateur radio systems as the following describes common practices followed by many to reduce risk.
--Dave, N9KMY

In the Shack: Single Common Mode Ground Point



Skyward Forum Suggested Ground Bar

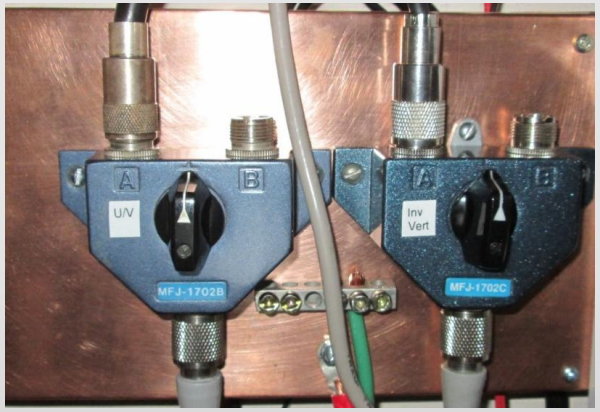
Jumpers Ready to be Attached to Equipment!

Large Cable or Strap To Shack Single Point Ground!

Short Cables to Shack Equipment

My Station Behind Radios

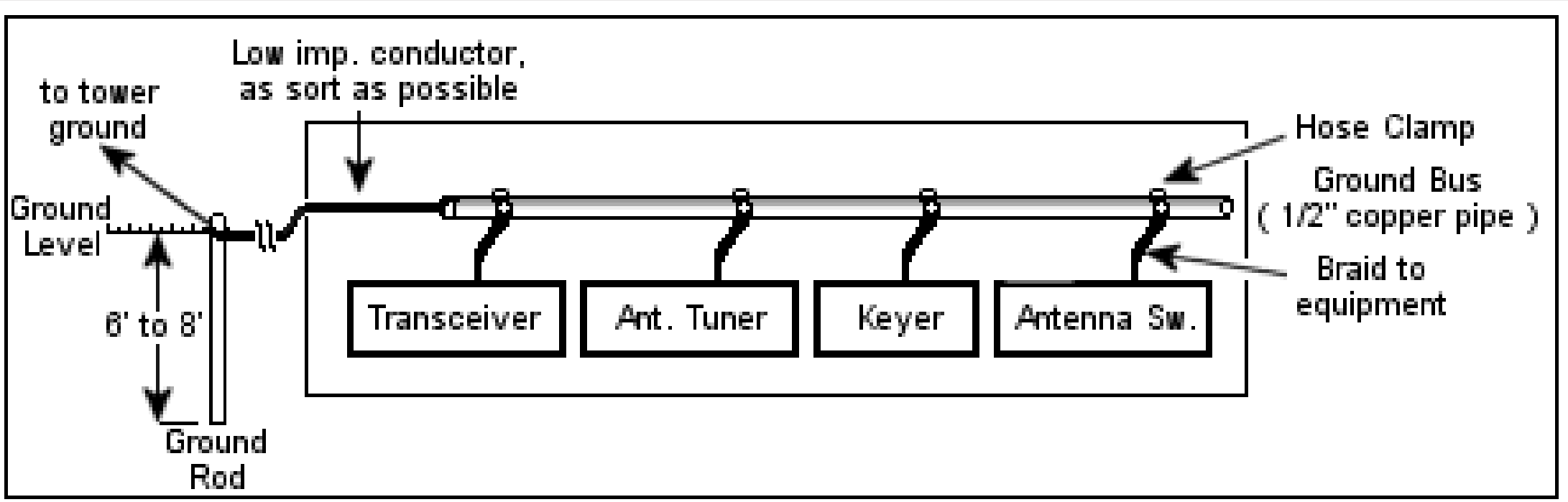
Cables from Antennas



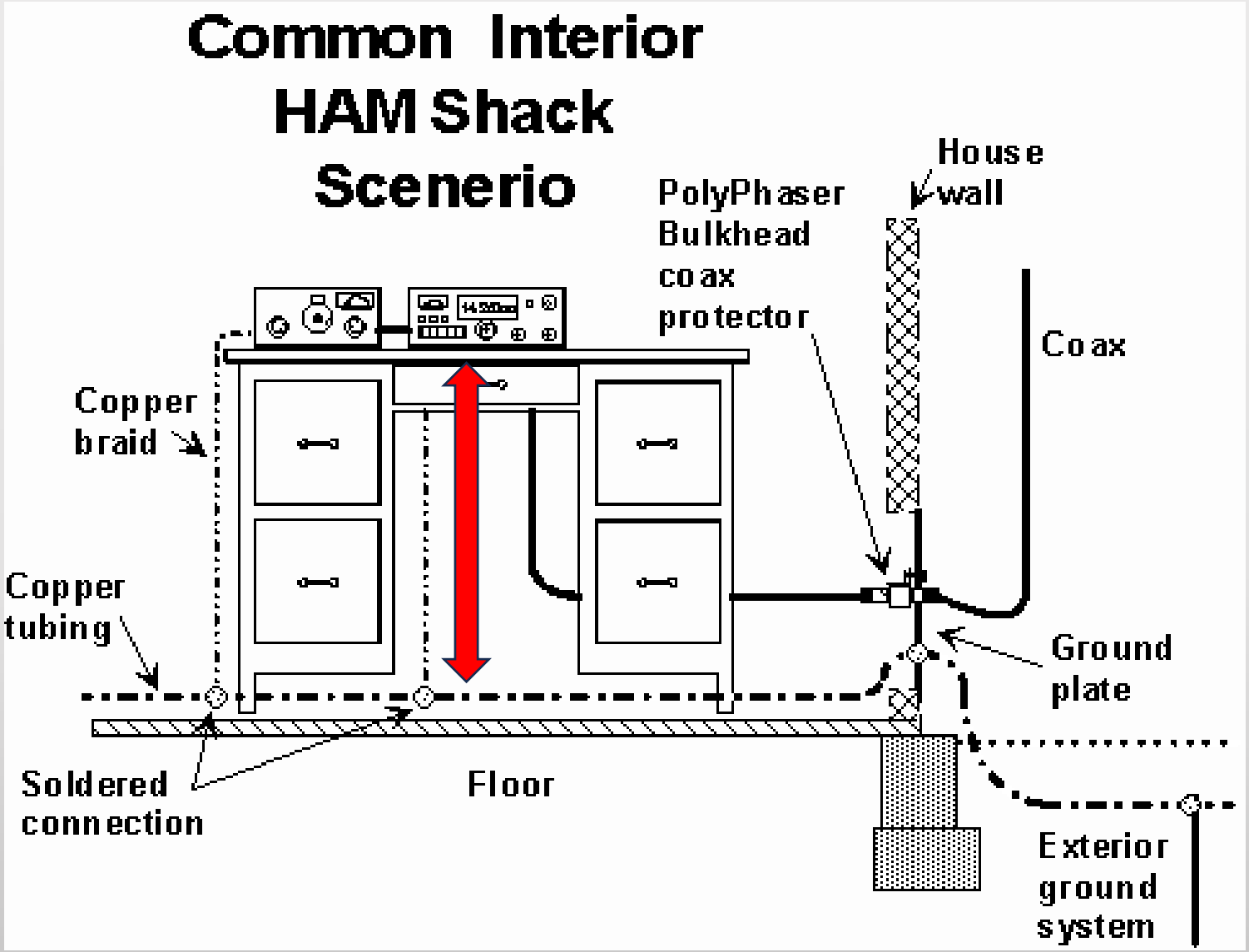
Cables to Radios

These switches, in center position, short center conductor to ground and copper panel is bonded .

Another Option for Shack per QSL. Net



<u>Why Short Bonding Cables</u>?
Single point grounding tends to break down at higher frequencies due to the length of the conductors.
<u>When conductors approach ¼ wavelength they become efficient antennas, thus bonding conductors should not be longer than 1/10th the wavelength of the highest frequency to be grounded</u>.



Let's Review and See What Might have been Done Better:

1. Desk Ground Buss Bar Too Far from Equipment.
2. No Bonding Cable to Building Entrance Ground
3. Better to have all equipment grounds to single point vs. bus

Length of Ground Cable to Ground Rod?

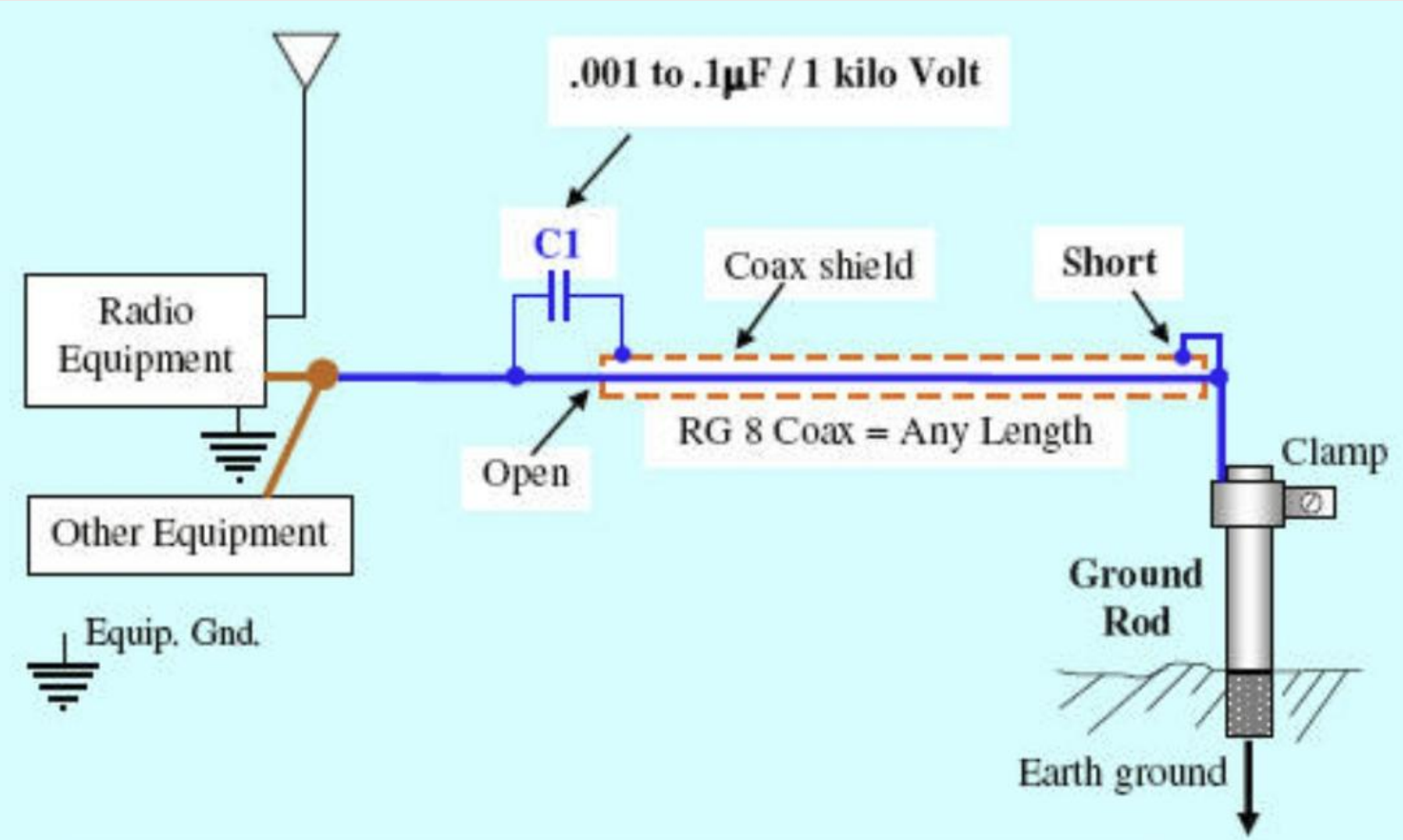


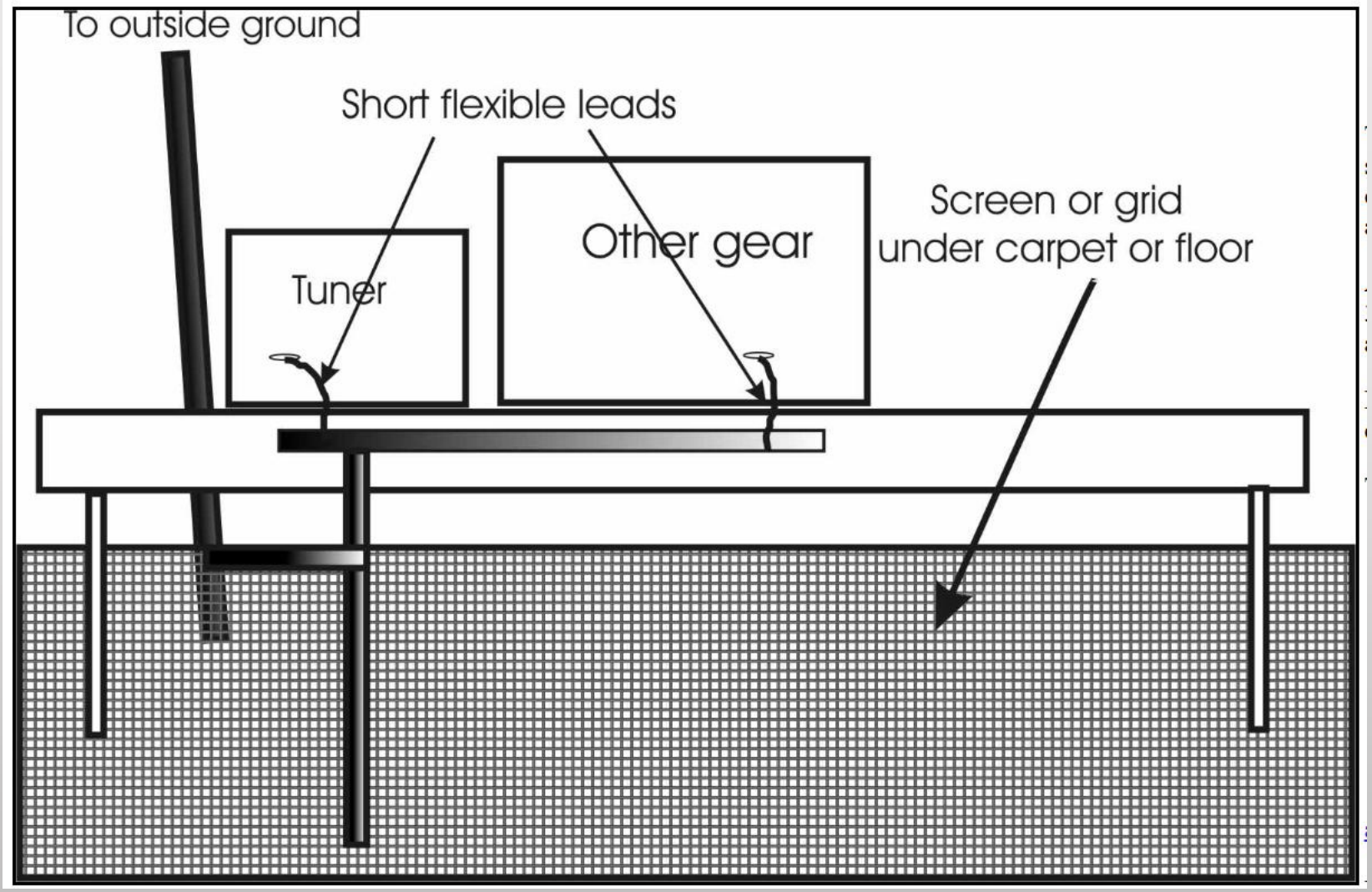
Fig. 7. RF grounding setup with the use of Coax transmission line (RG-8) for the radio equipment that is a long way to the ground rod.

A possible solution for an extra long ground cable, close to ¼λ (~30' or more). The capacitor value set by the length and note the break-down voltage.

Thanks to W8JI

Remember: Ground bonding cable is part of the antenna, especially at 80-10 meters.

How About an 2nd Floor Ham Shack?

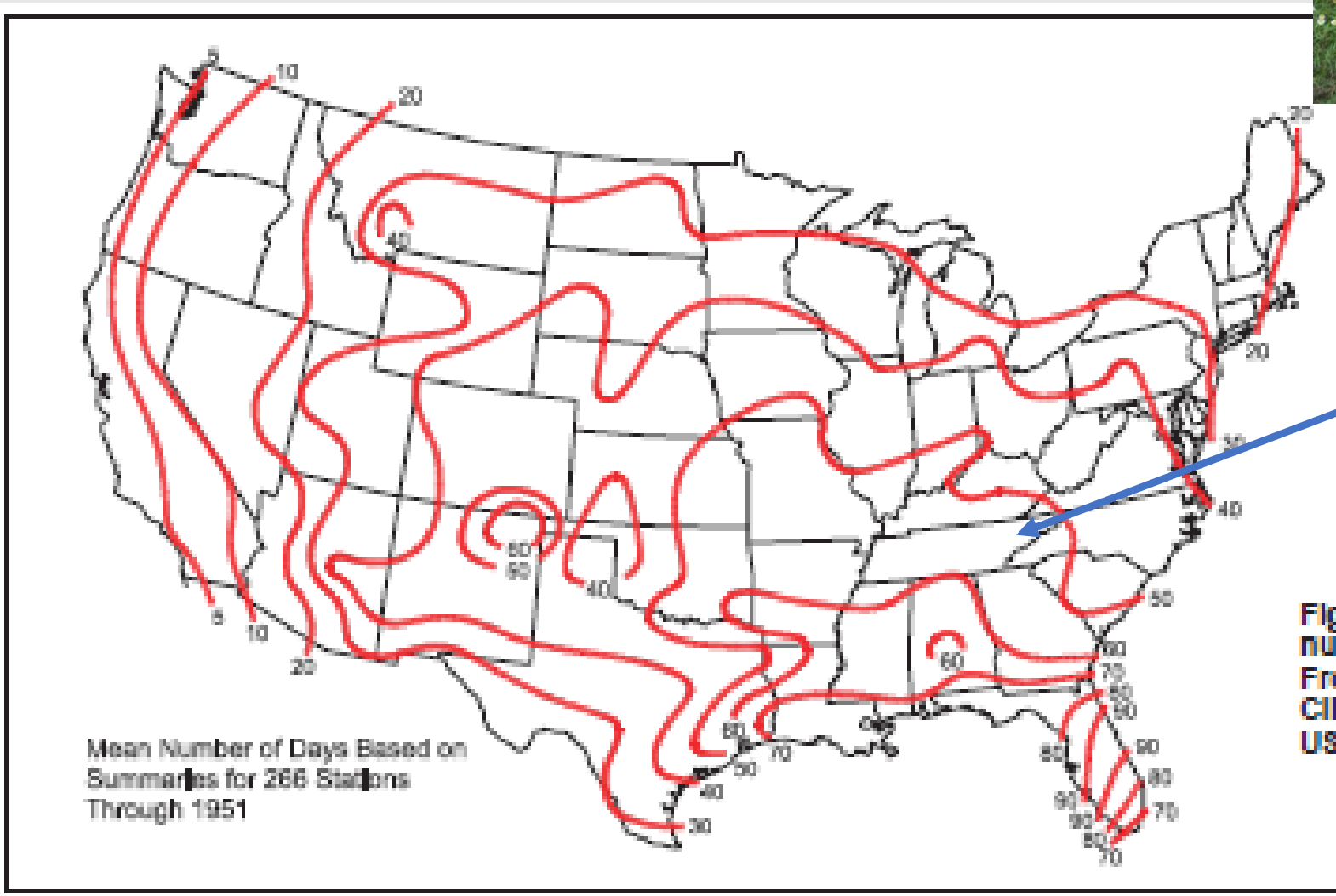


RF COUNTERPOISE
Installing a ground plane at room level is the most practical way to minimize RF in the above-ground shack. This ground system or more correctly ***counterpoise*** can be strips of foil laid under the carpet, a screen, or something under the floor. The conductive wide strips or screen should connect back to a wide station equipment ground buss.

Thanks to W8JI:
[Second floor grounding]

Lightning and Ground/Earthing

Lighting Storms per Year

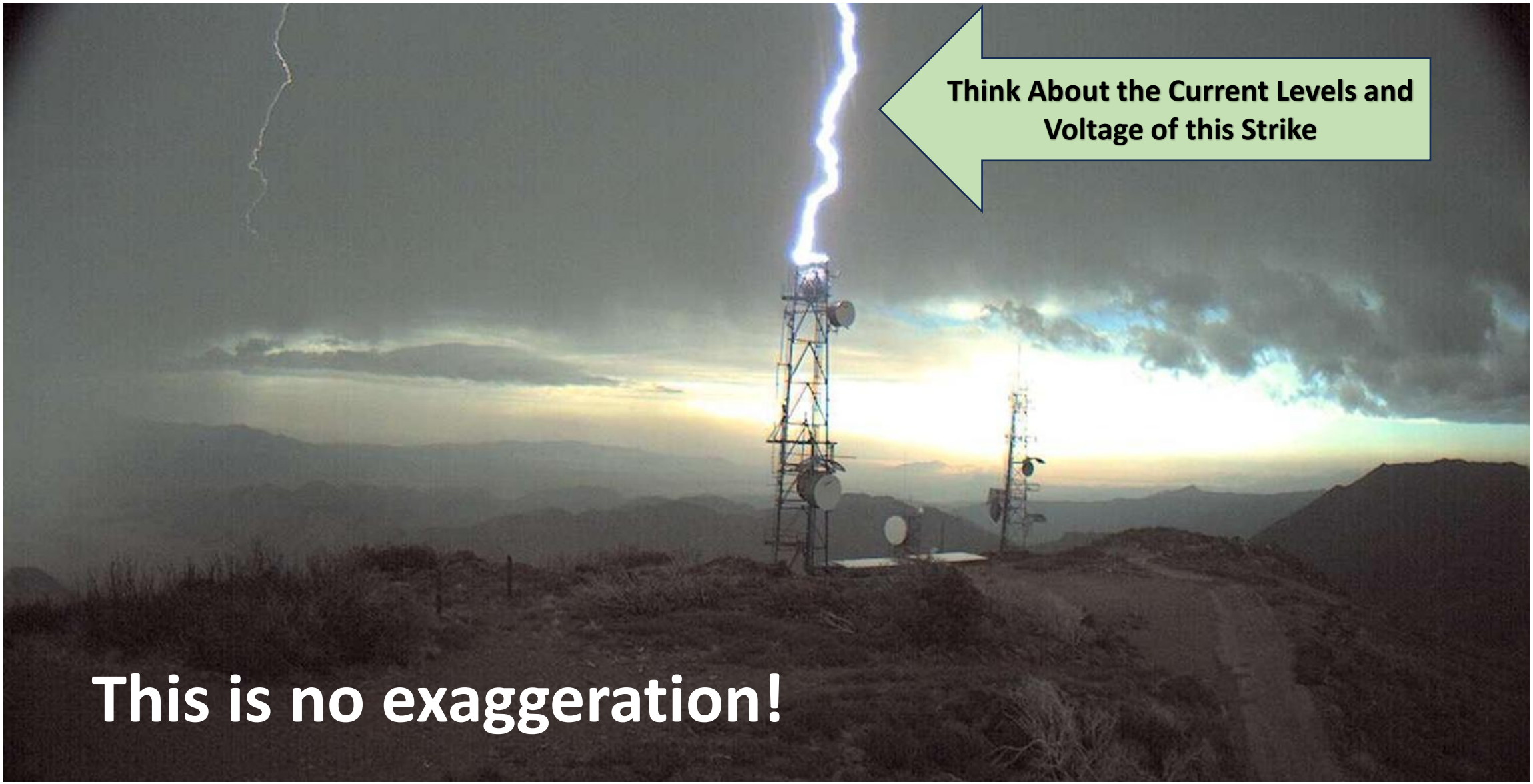


About 55 per year

Figure 2—This map shows the average number of thunderstorm days per year. From Technical Paper No. 19, Climatological Services Division, US Weather Bureau, 1952.

Lightning is a High Frequency Event

1) Charges in a cloud build up forming highly negative particles
2) Objects on the ground are positively charged
3) A negatively charged stepped leader is formed and moves downward in a haphazard ways forming surging steps (1usec pulse, 49 usec pause)
4) 3-4 branches of this stepped leader go in unpredictable directions
5) When the stepped leader is about 100 feet above the ground it finds a target and positive leaders surge upward from ground objects
6) A path is now formed and the electrons flow as a “return stroke”, 7ms



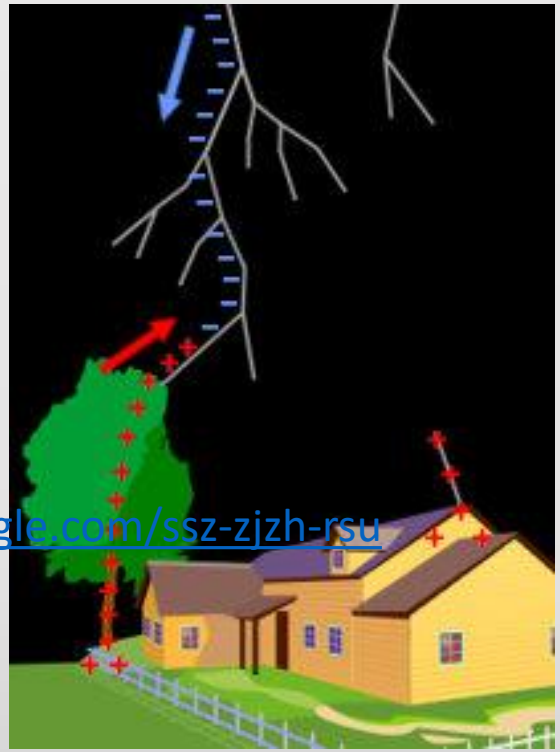
This is no exaggeration!

Lightning Steps 1 - 4

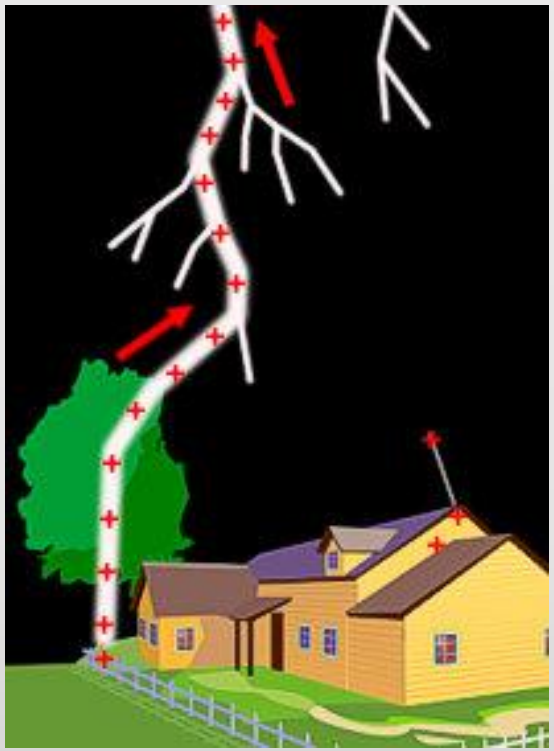
Stepped Leader – ZigZags

Leader Draws Streamers

https://meet.google.com/ssz-zjzh-rsu

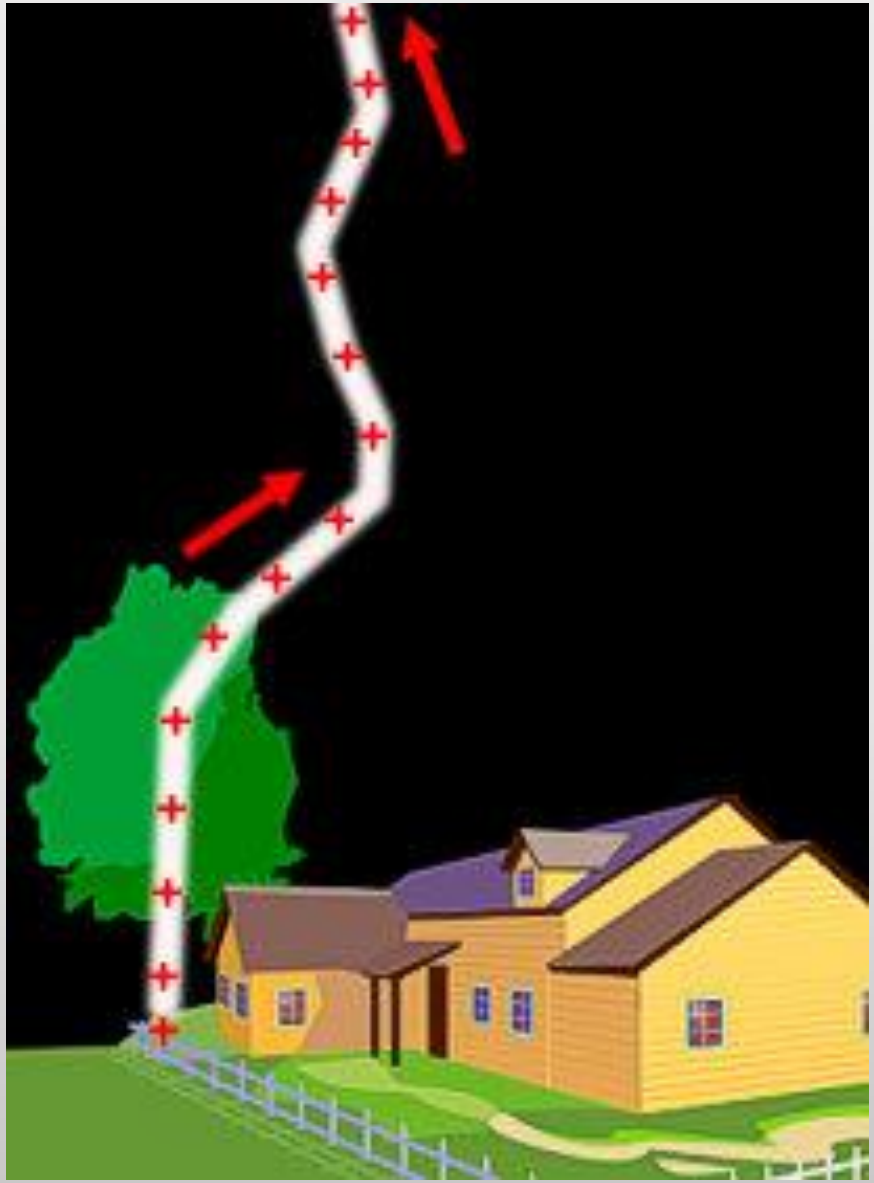


Connection Draws Current



Return Stroke Begins
60,000 miles/second
and about 7 ms duration

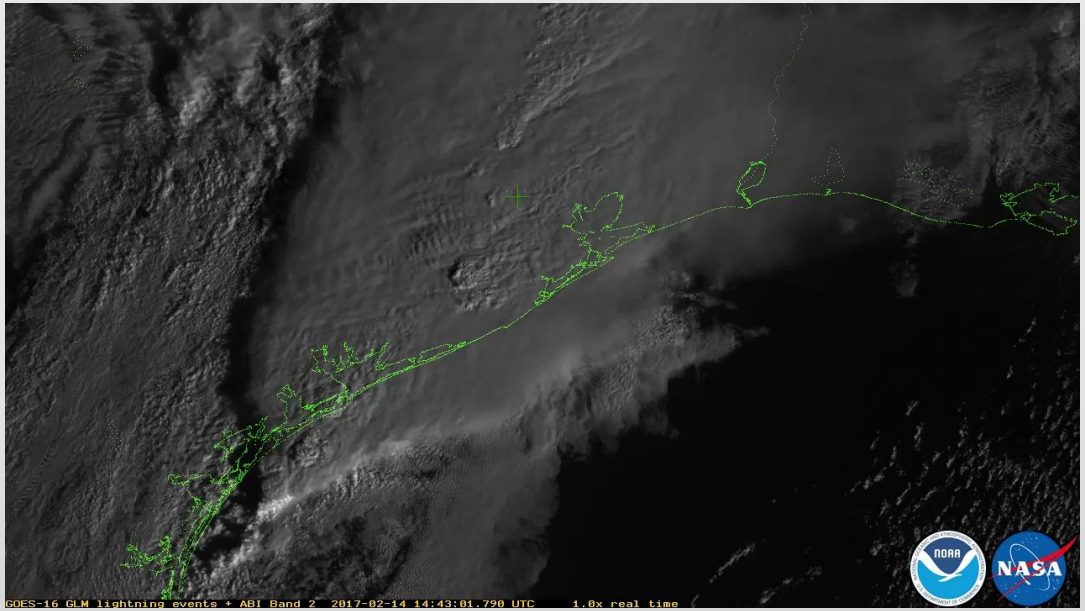
Drawings per NOAA

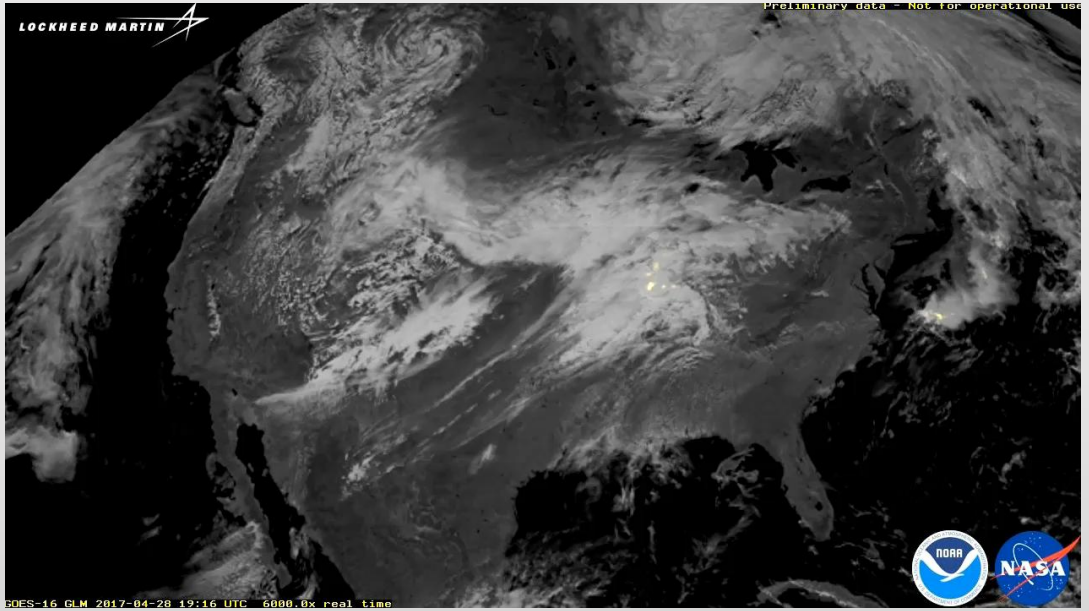


Strokes: 2-4 possible and 1-5 typically reach the ground

Lightning from Space

NOAA/NASA Images

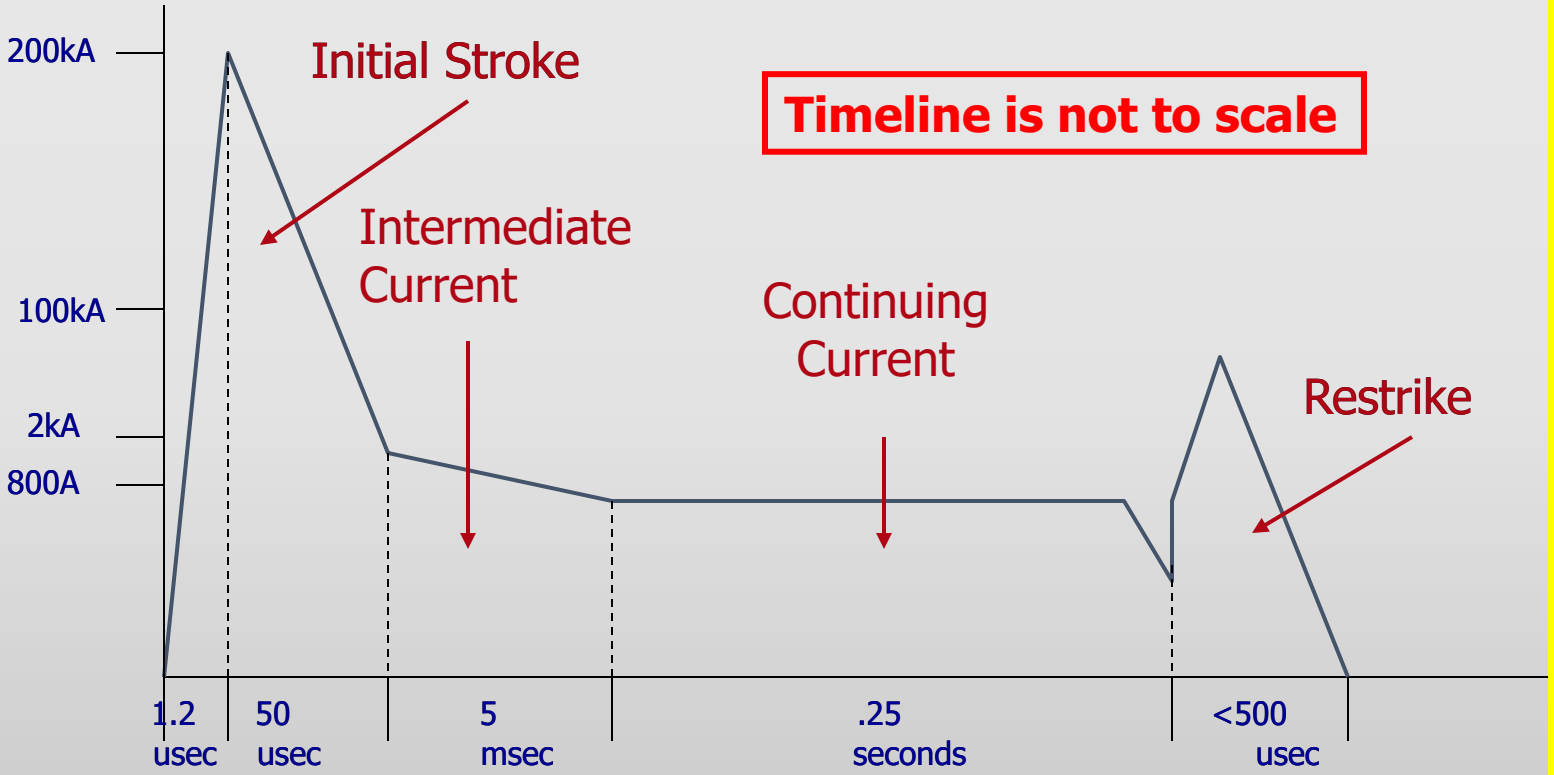




LEO Satellite Image with optical 777mn filter and time integrated filtering sending images every 90 minutes

GEO Satellite Image with spectral and time domain filtering sending images every minute

Anatomy of a Lightning Pulse



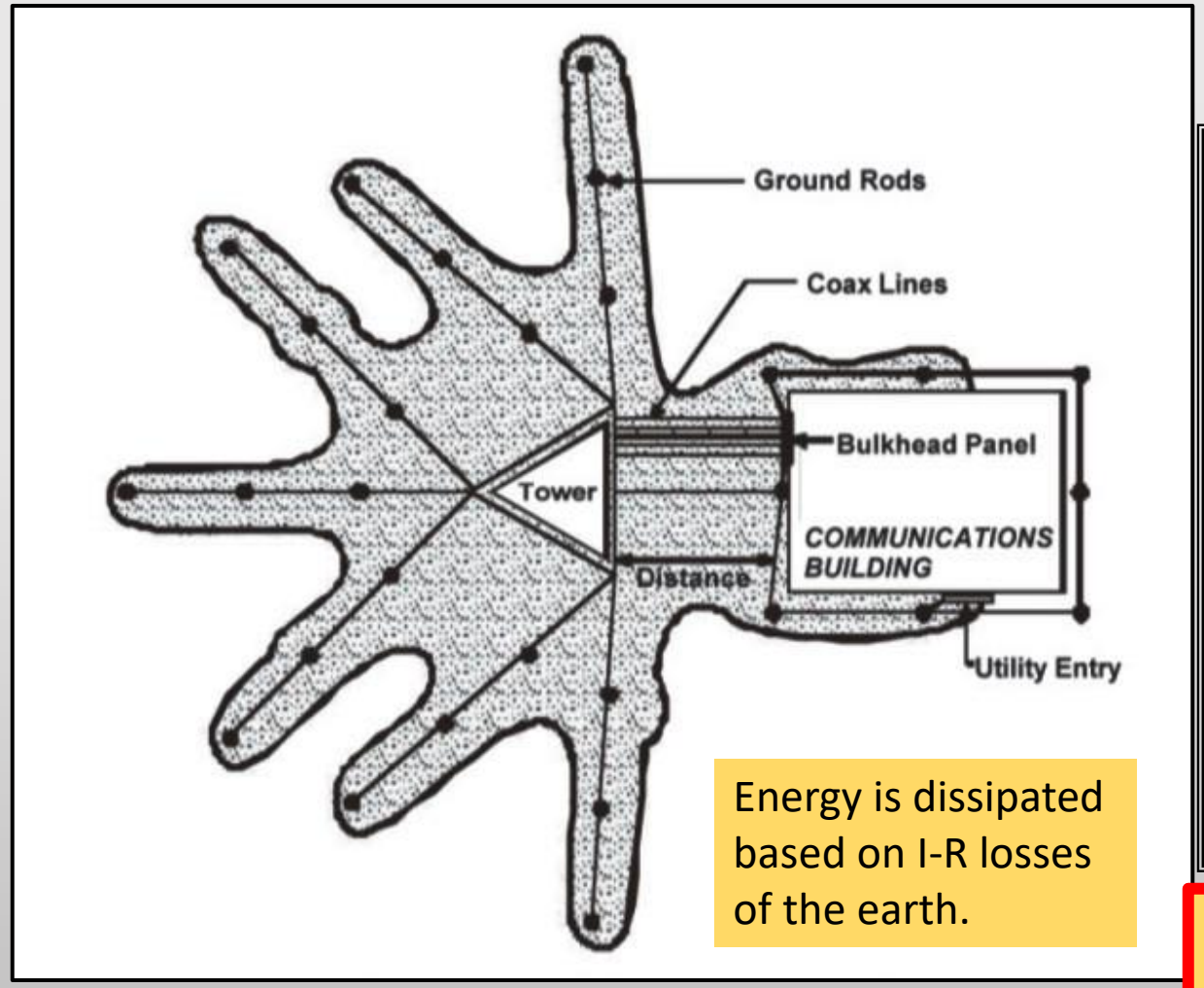
Timeline is not to scale

Average Strike is 18,000 amps with only 1% greater than 140kA

Myths & Legends

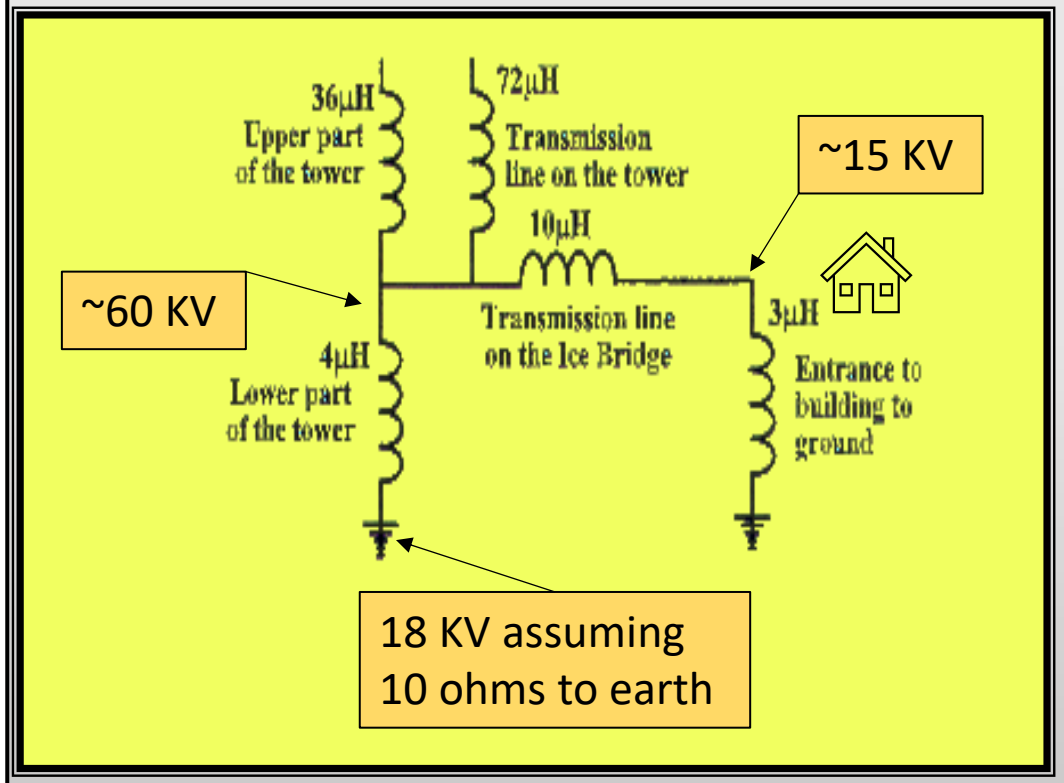
- Lightning never strikes twice in the same place
- Tower down conductors are needed
- Nothing can save you if you get hit
- Lie as flat as you can on the ground if out in the open
- A grounded tower is more likely to be hit
- Dissipation Arrays
- Lightning attractors/rods

Ground Dissipation of a Lighting Stroke



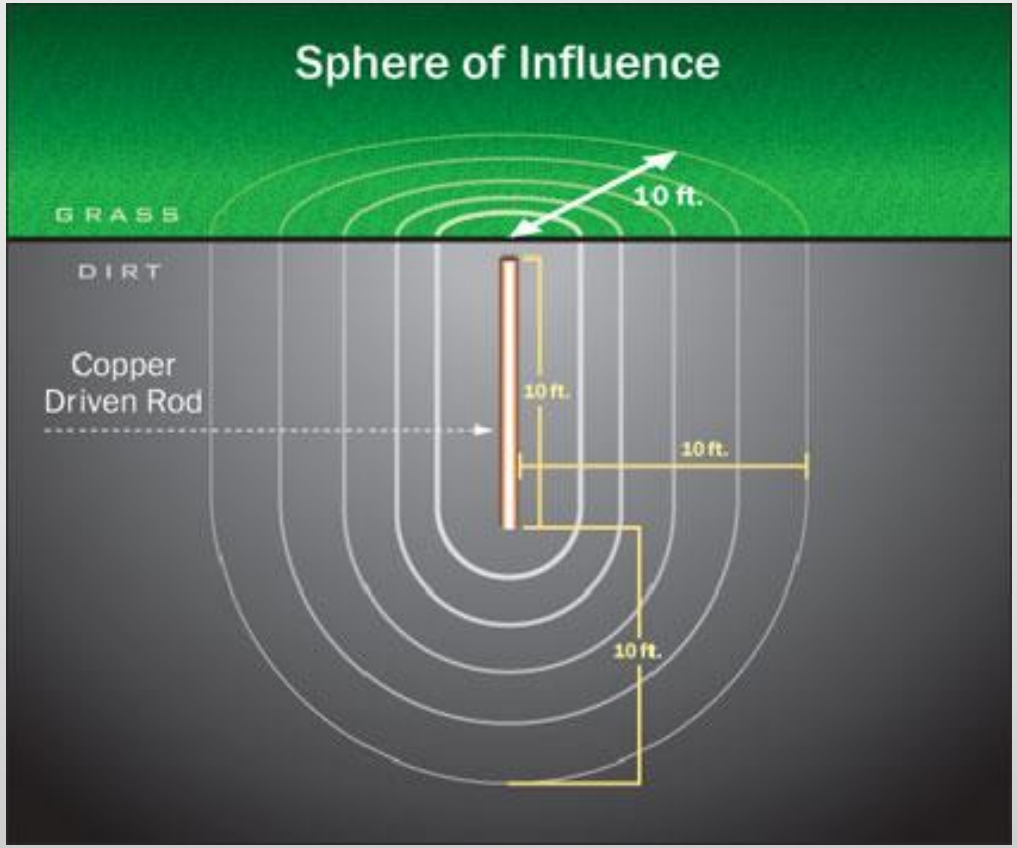
Energy is dissipated based on I-R losses of the earth.

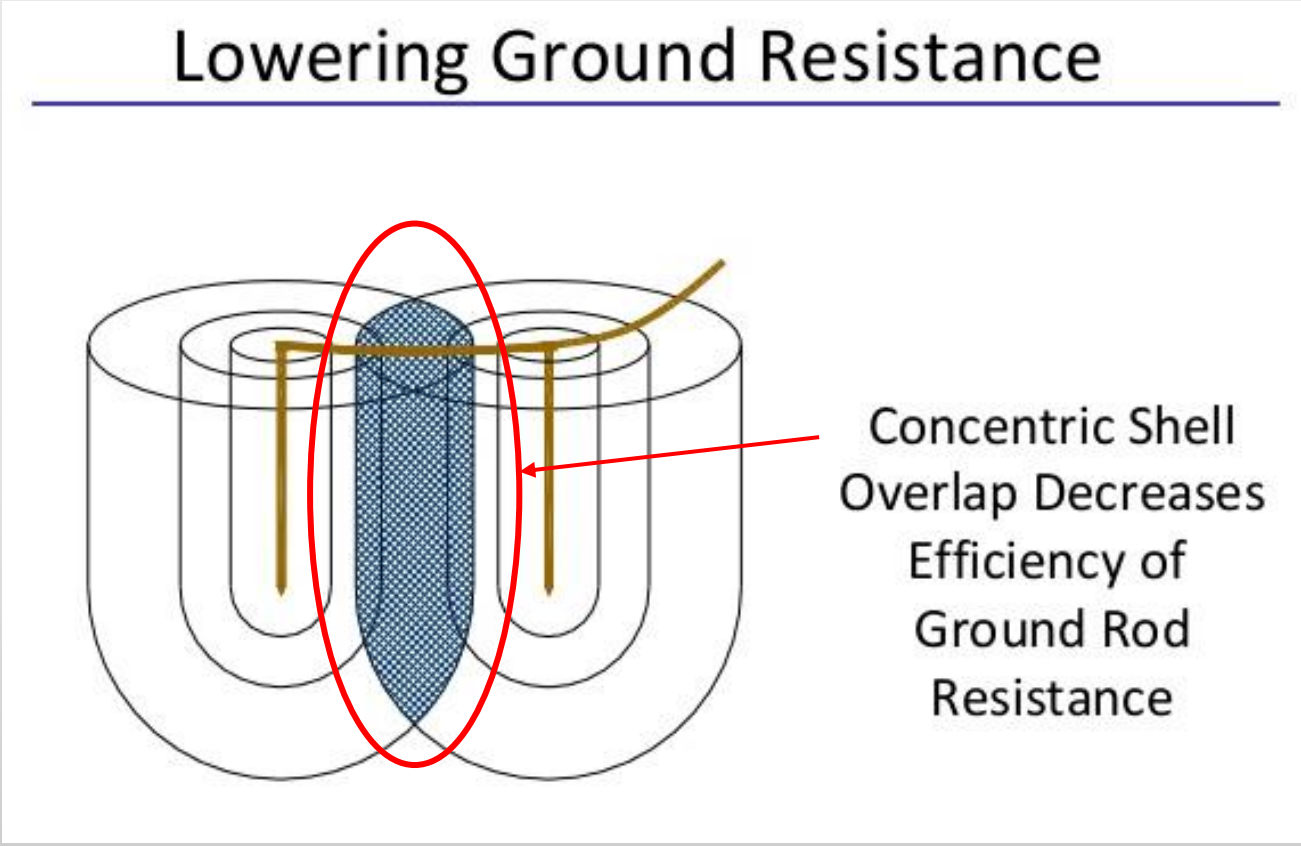
Typical 18-20 kilo amp – Top of Tower Hit



For every 1-ohm reduction in earth resistance reduces earth potential rise by 50 KV (per Novaris).

Ground rods placed too close together – Wasted $





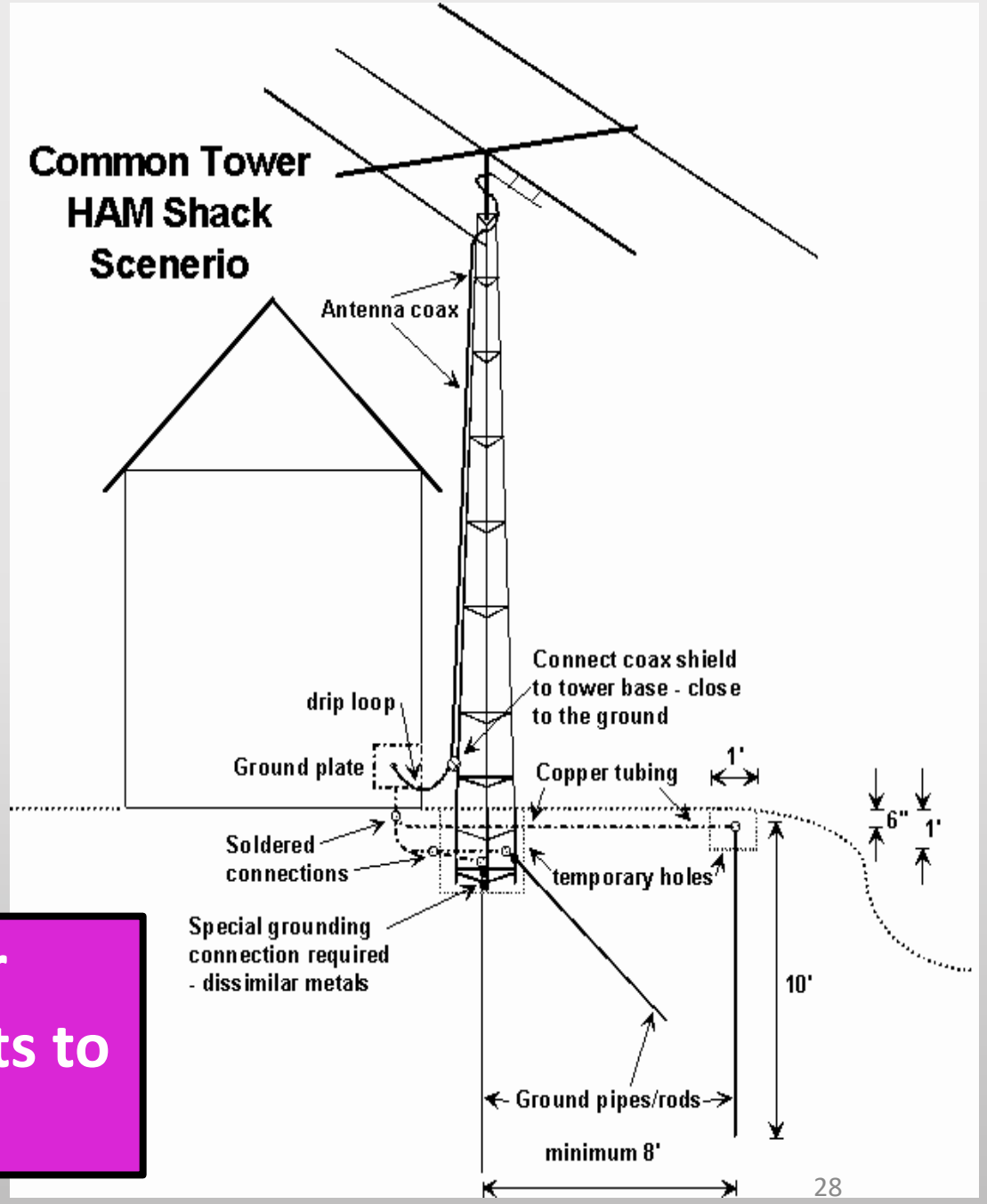
Ground rod minimum separation distance is the length of the rod to be effective. (A commercial tower has a minimum of 3 rods per leg with usually 6 if space permits.)

Let’s Review a Lighting Stroke Hitting a Tower

- Tower, transmission line and ground rods (electrodes) present both resistance and inductance to a lightning current surge.
- Electrical surge spreads along the tower as it heads to the earth.
- The bottom of the tower will **NOT** have zero voltage! **It can easily reach 60,000 volts** for a 1/4 second. Remember, this is **at the base**, the earth. Any conductors into the shack carry high voltage!
- More ground rods around the tower base and guys wires will reduce earthing resistance, however adding them also results in an increase of inductance, thus slowing down the dissipation of lighting current.

What Can You Do?

- **Obtain a copy of the ARRL book: "Grounding and Bonding for the Radio Amateur"**
- **Ground Tower/Antenna Support System**
- **More than One Ground Rod for Tower (3 to 4)**
- **<u>Bond All "Site" Ground Points</u>**
- **Surge Protect AC Power, Antennas, Comm Lines**
- **Create Single Point Ham Shack Ground**
- **Use Properly Sized Ground Conductors, as Short as Possible**



Solution? Do whatever possible to steer lightning current to the earth where it wants to go and before it reaches your shack!

OK, how about Surge Protection?

- Surges come from:
  - Nearby lightning hits via the power/communications lines to your home
  - Lighting hitting a nearby tree or other structure
  - Your antennas / supports
- There are four defined levels (types) of surge protection devices for power and each with different locations. All can be utilized.
- There are surge protection devices for communications:
  - Antenna feed lines
  - Rotor cables
  - Control cables

Disclaimer: You are on your own to do the best job possible to protect your amateur radio systems as these common practices may work for you to reduce risk. --Dave, N9KMY

AC Power Surge Protection – MOV/Selenium Cell

- Type 1 – Protects from externally produced surges {Line Side by Utility}
- Type 2 – Protects internally produced surges {Load Side}
- Type 3 – Individual outlet protection {Plug in Power Strip}
- Type 4 – Industrial end device protection {Wired In}

4

1

Under the Meter

2

At the Load Center

3

Near Equipment

Inside Equipment

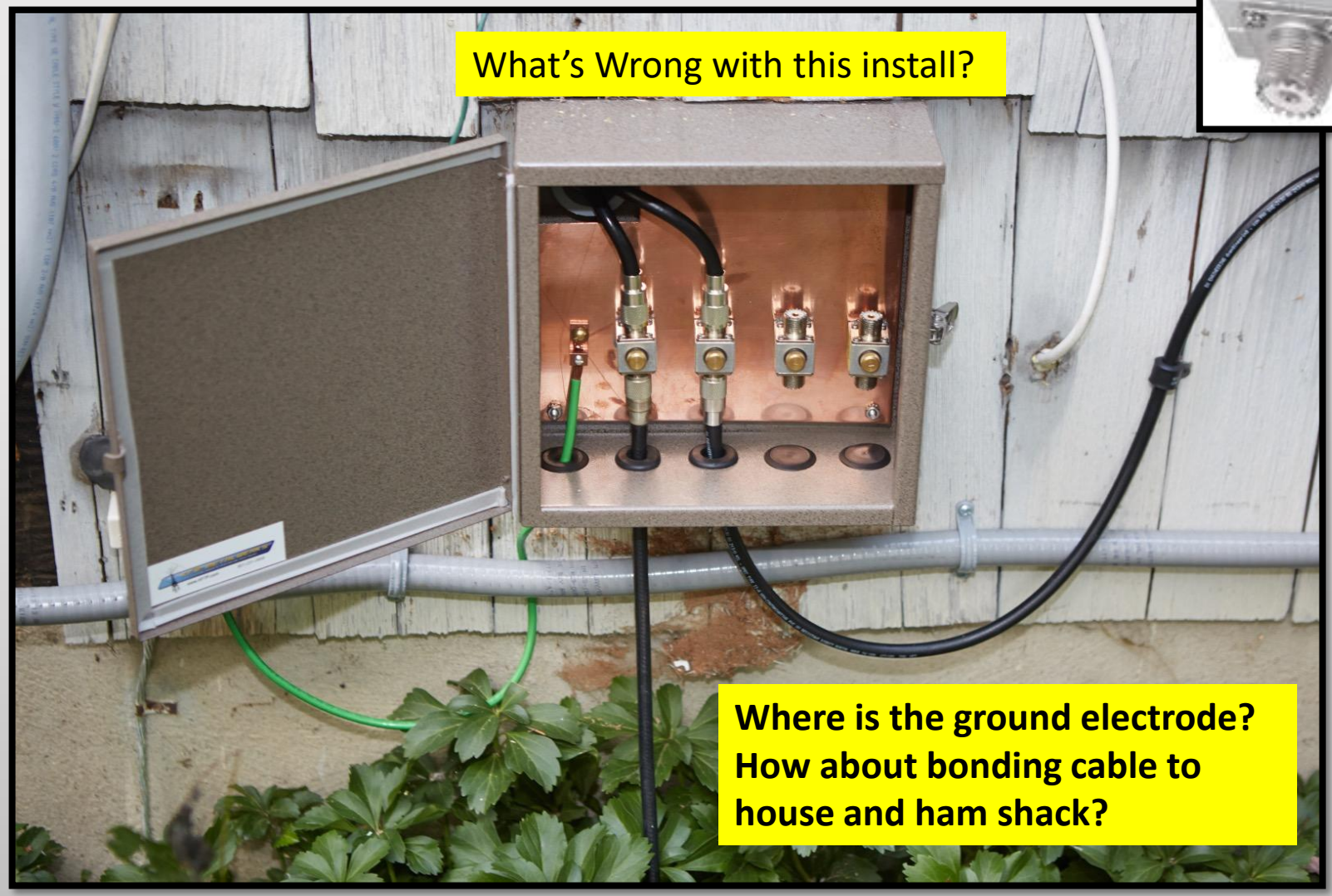
ULTRABLOK428 - Overview
Direct Plug-In Isobar Surge Suppressor Black Metal Housing

Premium protection for your expensive computer and audio/visual equipment, the Tripp Lite **ULTRABLOK428** ULTRABLOK Isobar® 2-Outlet Surge Protector features a surge protection to defend your sensitive electronics against even the strongest surges and spikes. In fact, Tripp Lite will repair or replace any connected equipment damaged by surges, including direct lightning strikes, up to $10,000 for life (valid in the U.S., Canada and Puerto Rico only).

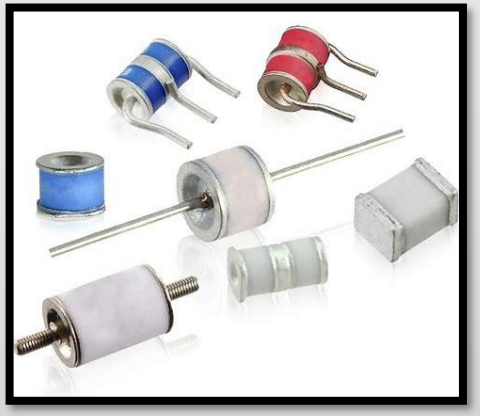
Surge / Noise Suppression

- AC Suppression Joule Rating: 1410
- AC Suppression Response Time: NM = 0 ns. CM = <1 ns
- Protection Modes: Includes full normal mode (H-N) and common mode (N-G / H-G) line surge suppression
- Clamping Voltage (RMS): 140
- AC Suppression Surge Current Rating: 48,000 amps
- AC Suppression Components Used: Metal oxide varistors, toroidal balanced chokes and VHF capacitors
- Safe Thermal Fusing: Prevents unsafe conditions during extreme extended over voltages and catastrophic occurrences
- EMI / RFI Filtering: 40-80 dB
- Immunity: Conforms to IEE 587 / ANSI C62.41
- Automatic Shut-Off: Yes

Coax Entry Point to Shack



Various Gas Discharge SPDs



A gas discharge tube is an electronic device that protects circuits from overvoltage by creating a low resistance path through ionized gas when a voltage surge occurs.

Other Approaches?

- Do Nothing and Hope for the Best!
- Disconnect Everything Every Time that Radios are Not In Use – **Do the Disconnect Outside!**

I have had two lightning events since we moved here with damage. I had a whole lot less damage 2nd time after updating my grounding.

Results of Bad, Improper or Failed Grounding/Bonding

- Devastating Consequences
- Electrical Fires & Property Damage
- Electric Shocks & Potential Electrocution
- Equipment Damage & Downtime

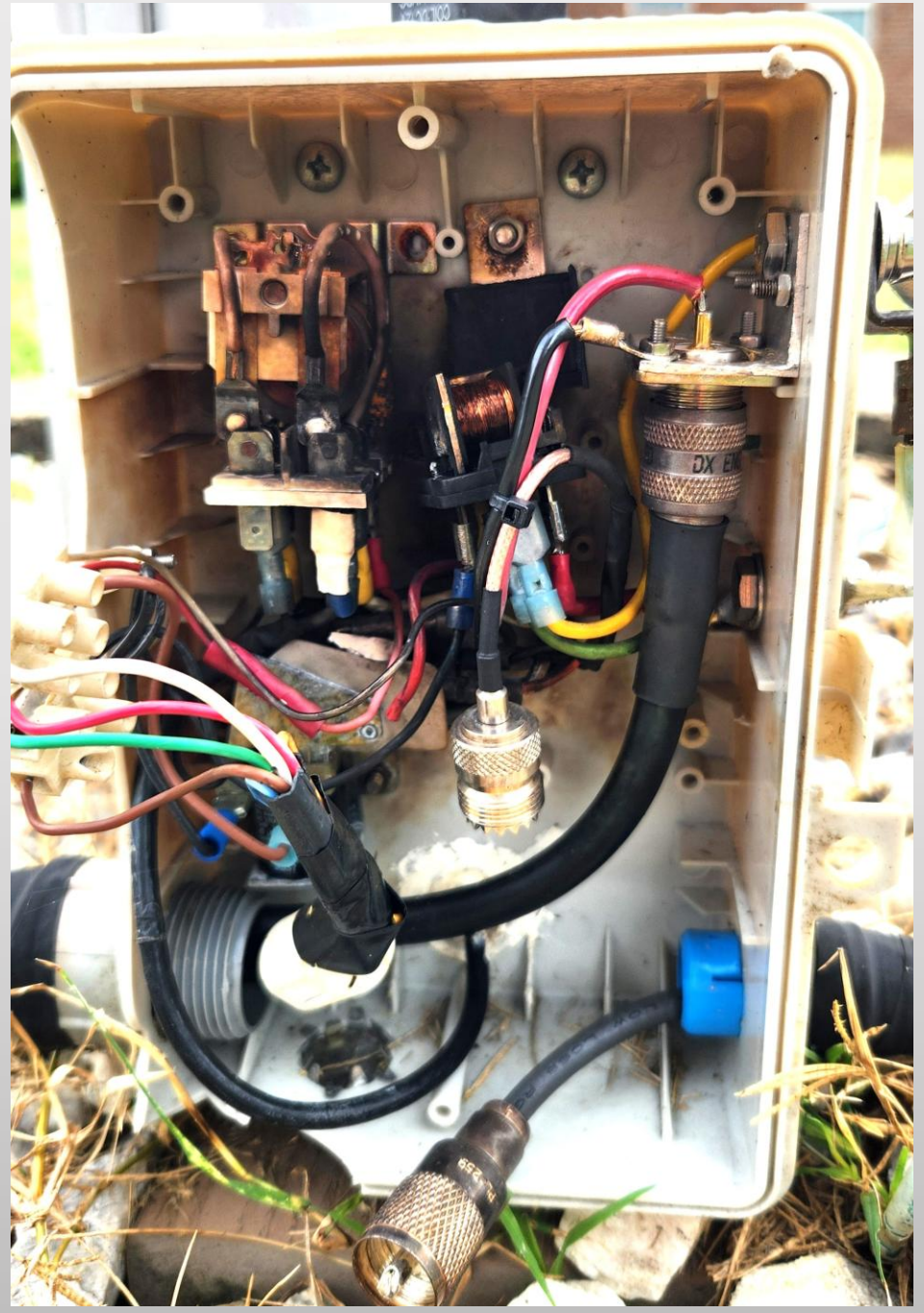
Remember **Bonding** Equalizes Voltage Potentials, thus reducing ARC/Fire Damage

First Lightning Hit 2021

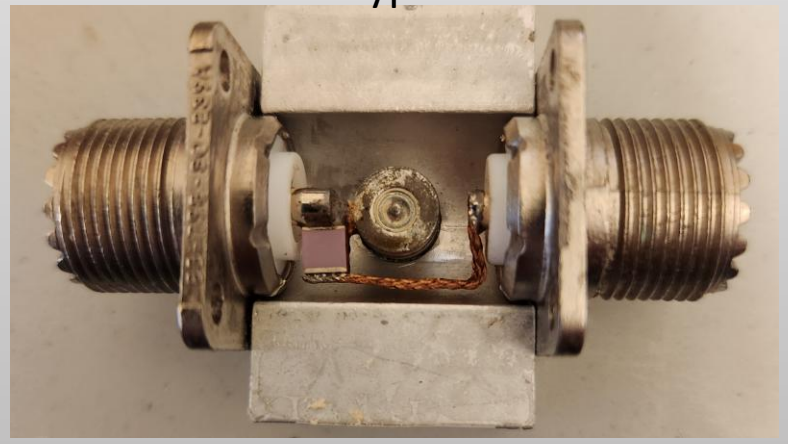
- Primary Hit to Nearby Power Pole and Cable TV (Internet)
- Secondary Hit to U/V Antenna Mounted to Roof (No Ground)
- Loss:
  - Antenna, Coax, SPD to Radio
  - Internet Modem/Router (Coax)
  - Wi-Fi Router/Switch (Cat 5. Ethernet)
  - Desktop PC (Cat. 5 Ethernet)
  - Television (Cat 5. Ethernet)
  - Yaesu U/V Radio FT-8900

Second Lightning Hit 2025

- Hit to OCF 40-10M Antenna
- Surge into House via Coax and Antenna Switch Control Cable
- Loss:
  - Antenna Switch Relay Controller
  - Controller: Antenna Switch
  - Laptop PC
  - USB Hub
  - Coax Surge Protector
  - Yaesu U/V Radio FTM-300
  - Video Monitor

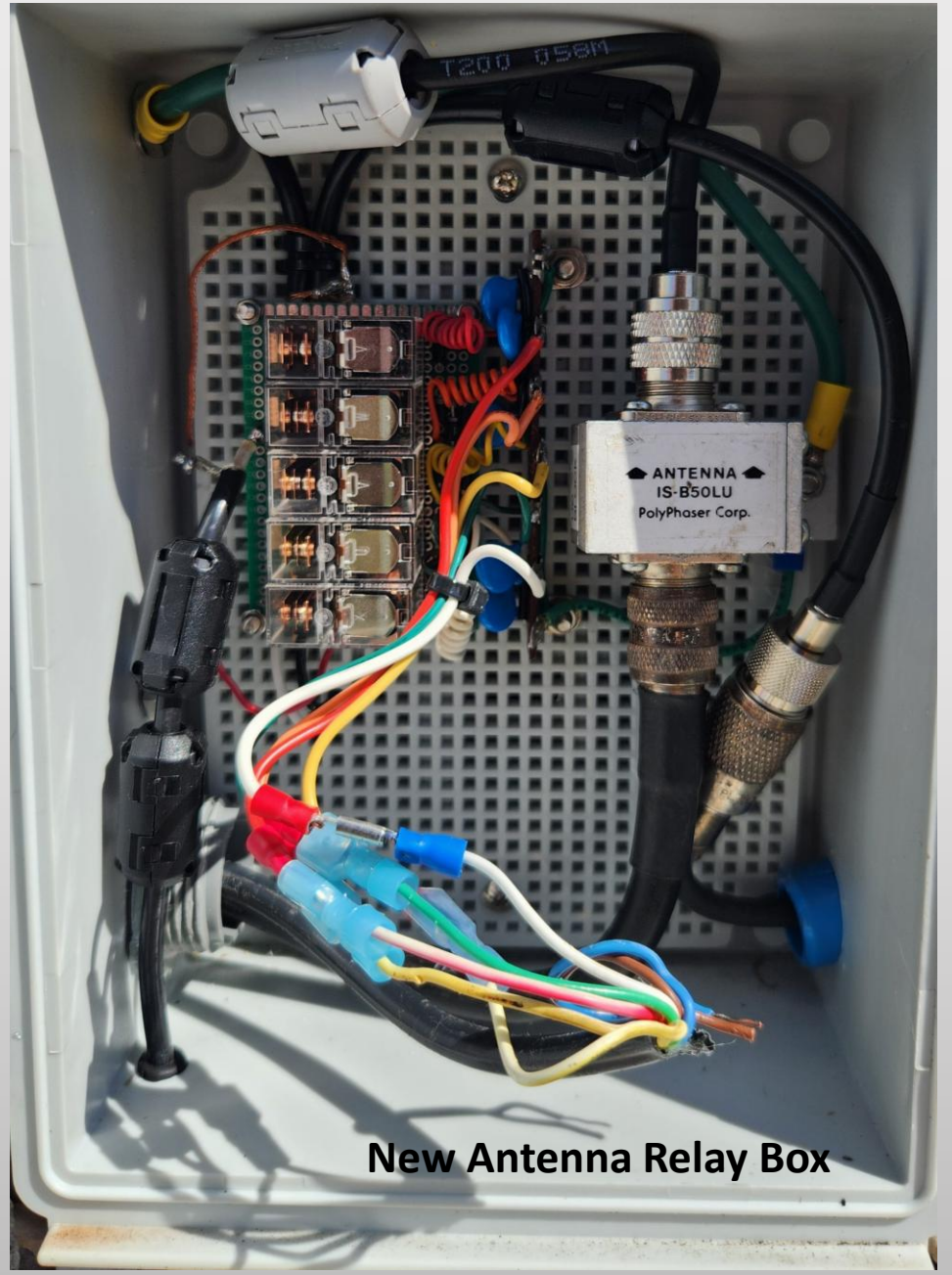


Inside Polyphaser SPD



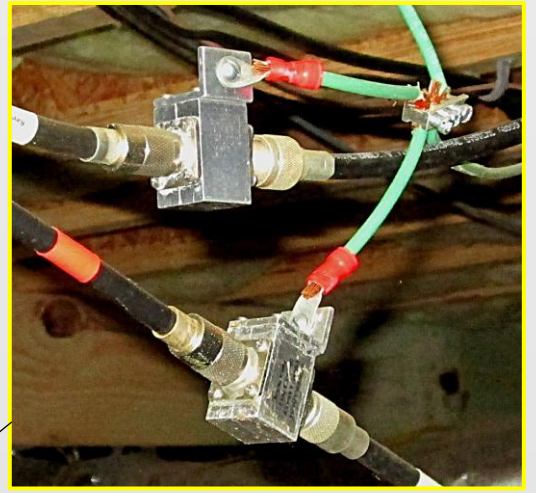
Gas Discharge Tube

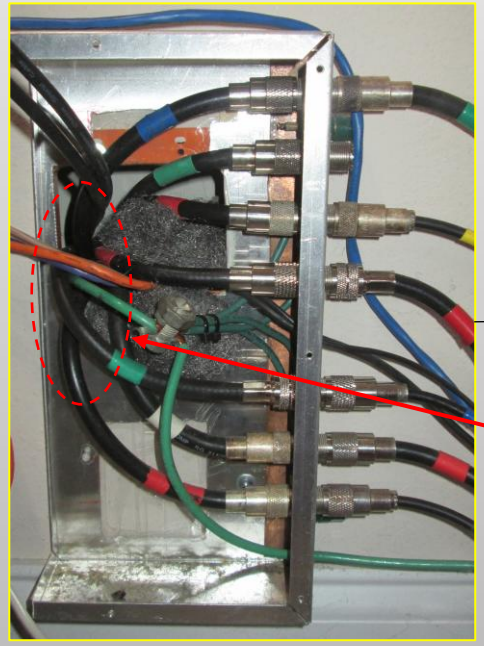
What Am I Doing Today?



New Antenna Relay Box

My Home





Unattached Garage

SPD

U/V Vertical, 6M/10M Dipole, and VHF J-Pole Ant in Attic

Grnd Rods

Grnd Rod

OFC Antenna

Home Load Center

UHF Vert Antenna

Coax in crawl space

Flagpole Ant and Relay Box plus 60 radials. Arc gap to

Grnd Rod, SPD & Arc Gap

#6 Grnd Bond Cable in crawl space

Ham Shack

Deck

Buried Pipe w/ Coax & Relay Cable

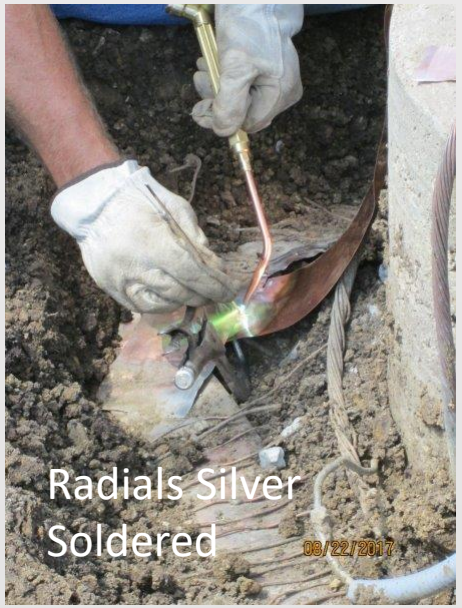
Cables down to crawl space

U/V/6M Ant and Ground Rod

Cable Entry, Single Point Ground. Each coax and remote relay control cable has SPD.

Questions


No Copper Strap was Used
08/22/2017

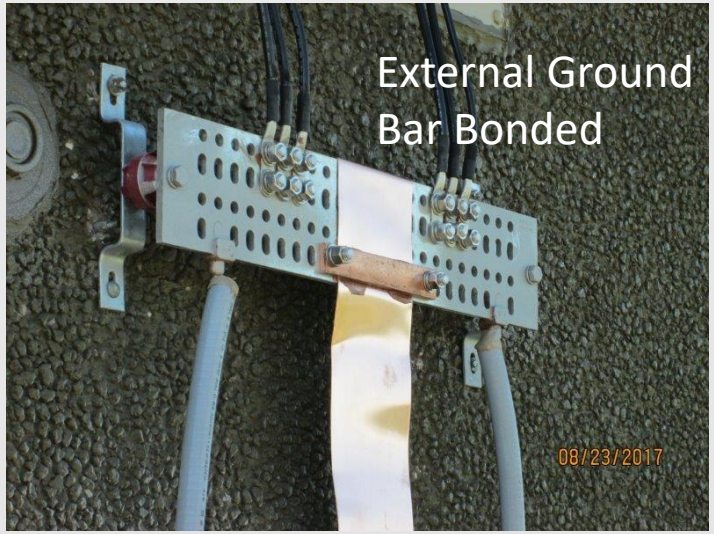

Radials Silver Soldered
08/22/2017

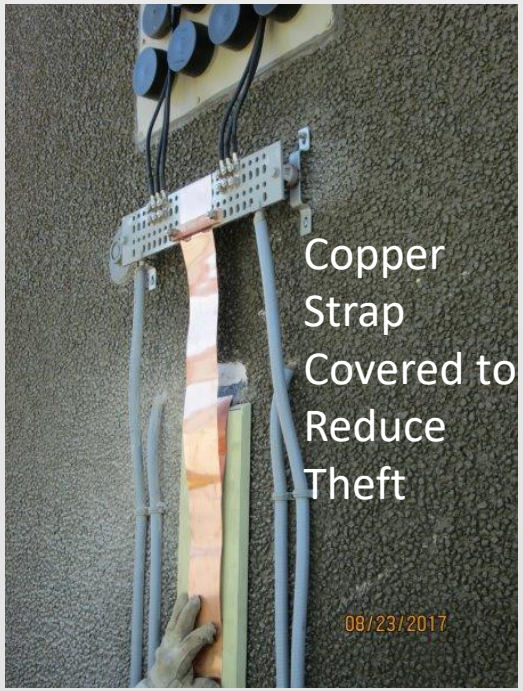

Copper Strap was Added
08/22/2017


Copper Strap was Extended to Building
08/22/2017


Copper 2” x 2” grid Screen Installed
08/22/2017
Updated Tower Grounding of AM Site

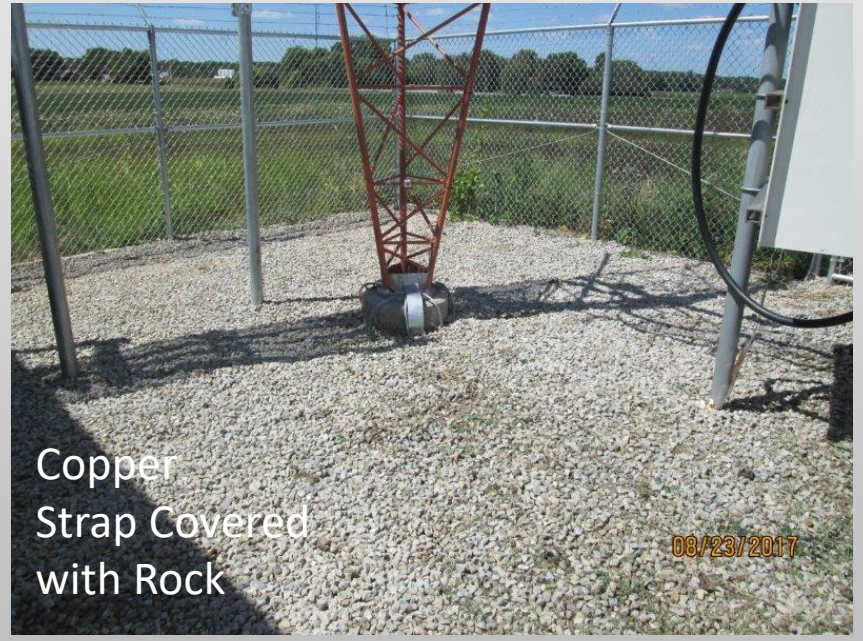

Copper Strap Bonded to Tower
08/22/2017


External Ground Bar Bonded
08/23/2017


Copper Strap Covered to Reduce Theft
08/23/2017


Copper Strap Painted to Reduce Theft
08/23/2017


Copper Strap Bonded to Master Ground Bar
08/23/2017


Copper Strap Covered with Rock
08/23/2017


Only 2.43 amps vs. 60 amps RF previously
08/23/2017