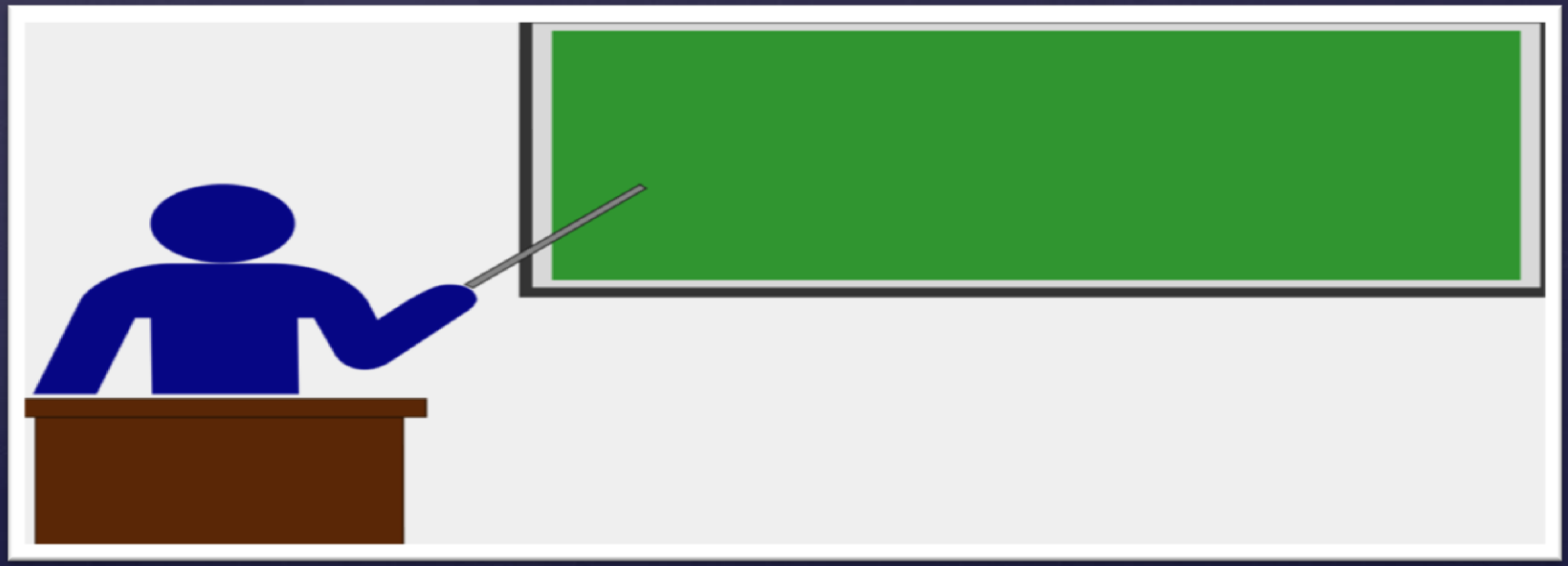
Bonding and Grounding

(and hopefully, lightning protection)

Dennis Smith WB5SRM

This presentation covers the bonding and grounding techniques used in the construction of our home on Lake Palestine.

It also highlights some interesting information I gleaned while researching this project. There may be things that I missed but this was the consensus I came up with after much research.



BUT FIRST!!!
Some boring facts…

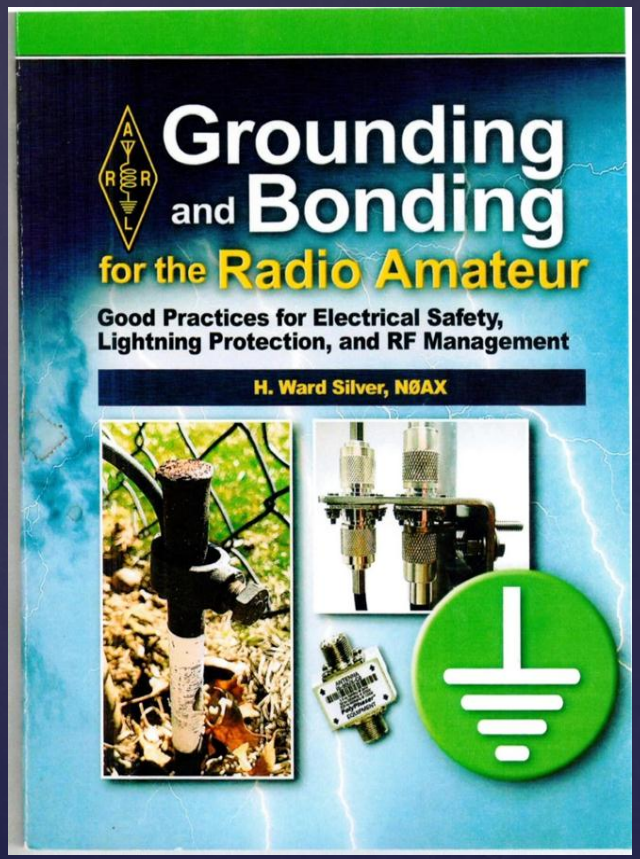
A good ground is very important, maybe the most important thing, in mitigating lightning damage; the more energy you can divert to ground before it gets into the house or equipment room, the less you have to deal with through lightning and surge arrestors. More importantly, more energy diverted to ground means less can go through your electronics!

Lightning Protection

- **Redirect**
  - Spark gap, gas discharge to ground system
  - Ground **ALL** antenna support structures
- **Modify**
  - L/C low pass filter, long coax run
- **Block and Shunt**
  - Inductor to ground system for static and pulse
  - Spark gap to ground system for pulse and quench
  - Series cap for RF to block LF and DC pulse
  - Resistor to ground to protect equipment

Lightning and Protection Grounding K5KM (SK)

If You Intend To Do Any Grounding Projects, **Use These Books!!!**



Why We Have Lightning “Issues”

My Only Tree for “Defense”

Three types of grounding

1. Safety ground

Prevents shock

(so you don't get the slobber knocked out of you)

2. Lightning ground

Providing a low impedance to earth

3. RF ground

Against which electrical potential is measured

(fancy wording for antenna ground)

Some strikes are worse than others….

The magnitudes of lightning discharges around the world have been measured from 2000A to more than 200kA, with rise times to peak current of less than 10μs. The variation in magnitude and rise times follows the 'log-normal' distribution typical of many natural phenomena. BS6651 gives the following data:–

99% of strokes exceed 3kA

90% of strokes exceed 8kA

50% of strokes exceed 28kA

10% of strokes exceed 80kA

1% of strokes exceed 200kA (game over)

MTL Surge Technologies Application note 1002

Why electronics are more susceptible to surges

solacity.com

More transistors per chip and smaller trace widths make modern equipment increasingly susceptible to surges.

Year	Model	Transistors	Speed	Trace width
1971	4004	2,300	0.1 MHz	10.00micron
1974	8080	6,000	2.0 MHz	6.00 micron
1978	8086	29,000	5.0 MHz	3.00 micron
1982	80286	134,000	8.0 MHz	1.50 micron
1985	80386	275,000	16 MHz	1.00 micron
1989	80486	1,200,000	25 MHz	0.80 micron
1993	Pentium	3,100,000	60 MHz	0.60 micron
1998	Pentium II	7,500,000	400 MHz	0.25 micron
2001	Pentium IV	42,000,000	2000 MHz	0.13 micron

Latent Damage

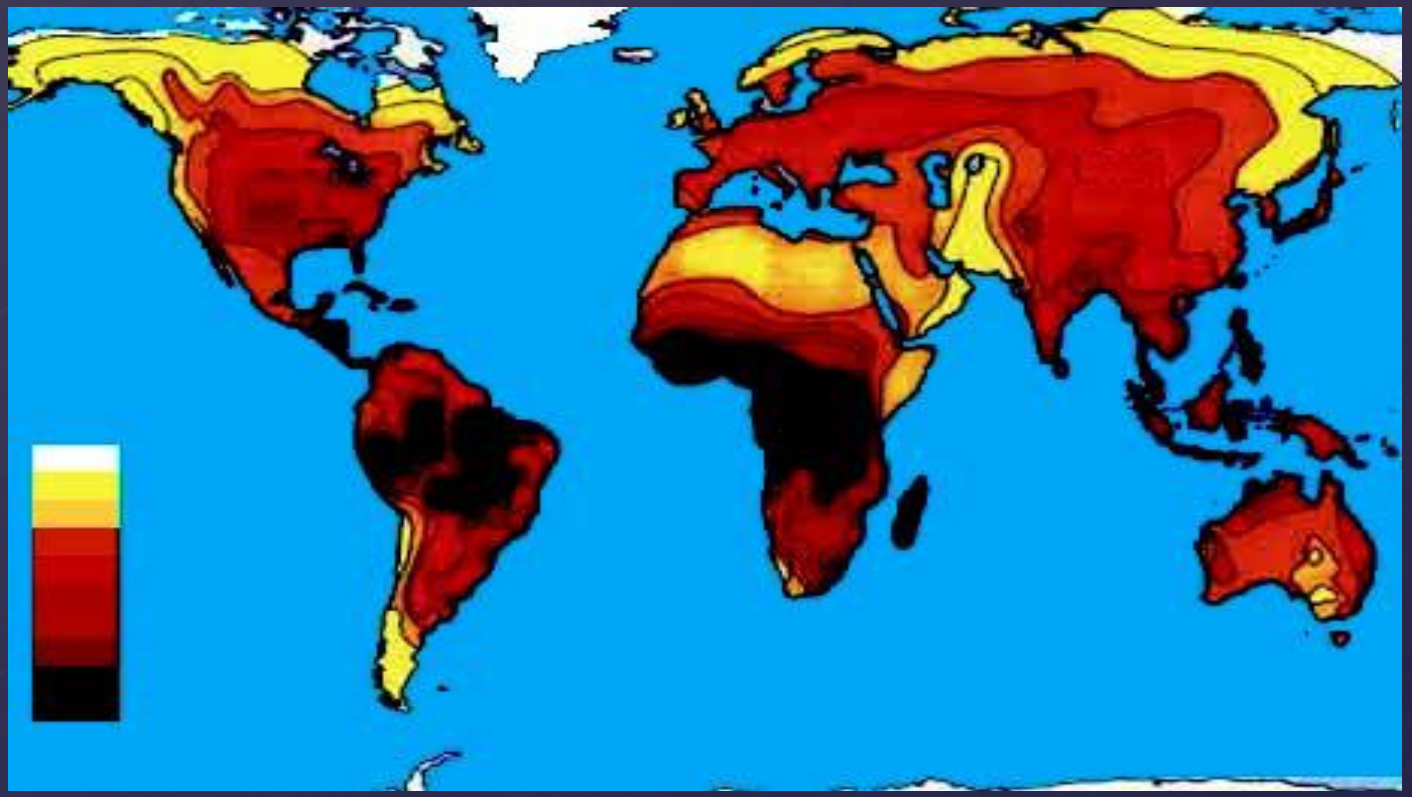
Stress to electronic components can cause failure at a later date. The US military has spent large sums of money to study what has been termed “latent damage”. Latent damage leads to reduced MTBF (Mean Time Before Failure) of equipment. Lightning stress from coupled magnetic fields to high speed, small junction semiconductors, can lead to unexplainable failures.

PolyPhaser; Tower strikes & Solutions

A thunderstorm day is a local calendar day on which thunder is heard ***regardless*** of whether lightning flashes are nearby or some distance away. To an observer at a specific location, the average distance at which lightning may occur and thunder may be heard is about 6 miles.*

*From the U.S. military handbook 419a-grounding

LIGHTNING ACTIVITY AND EXPOSURE



Average Number of Thunderstorm Days/Year (isokeraunic map)

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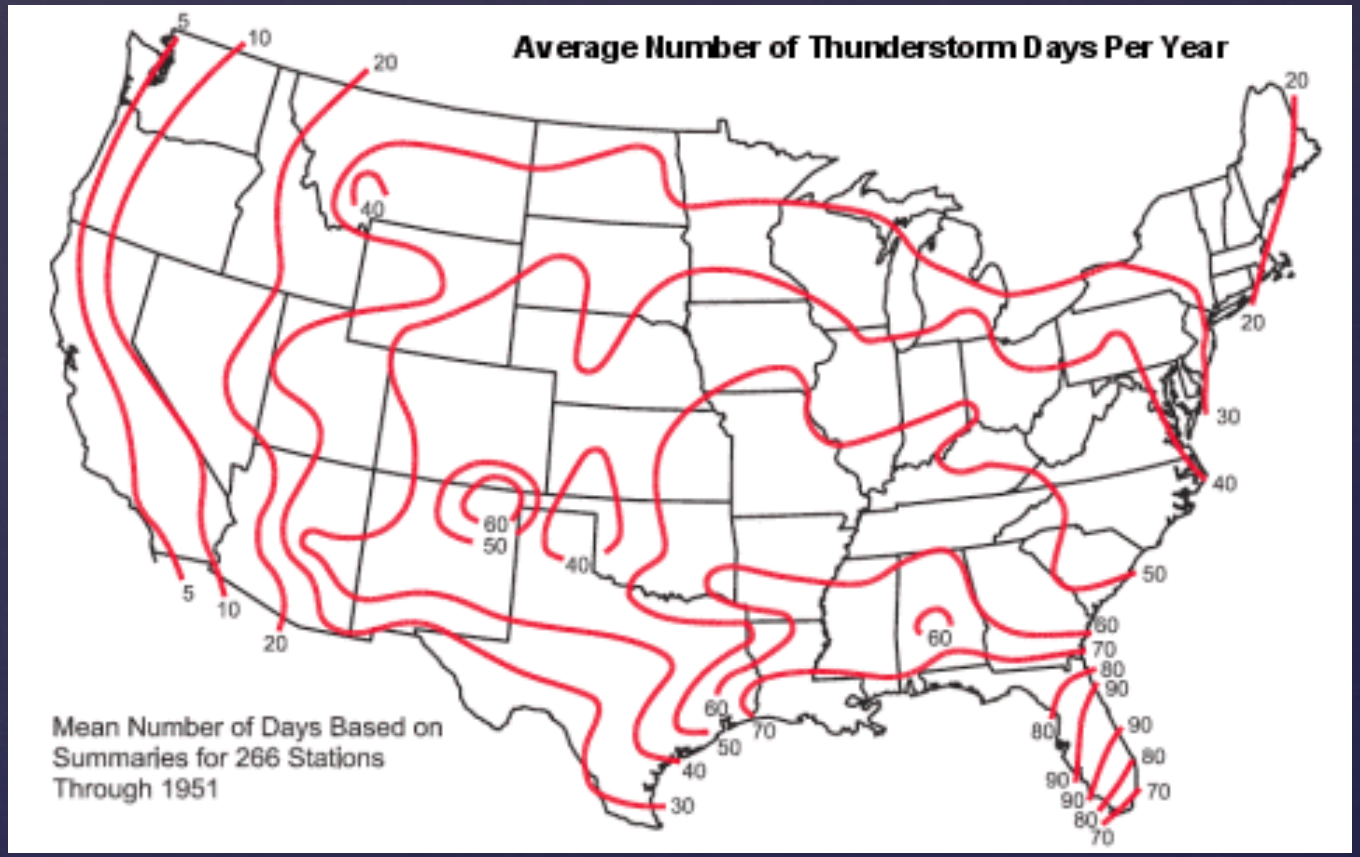

Lightning Strikes vs. Tower Height

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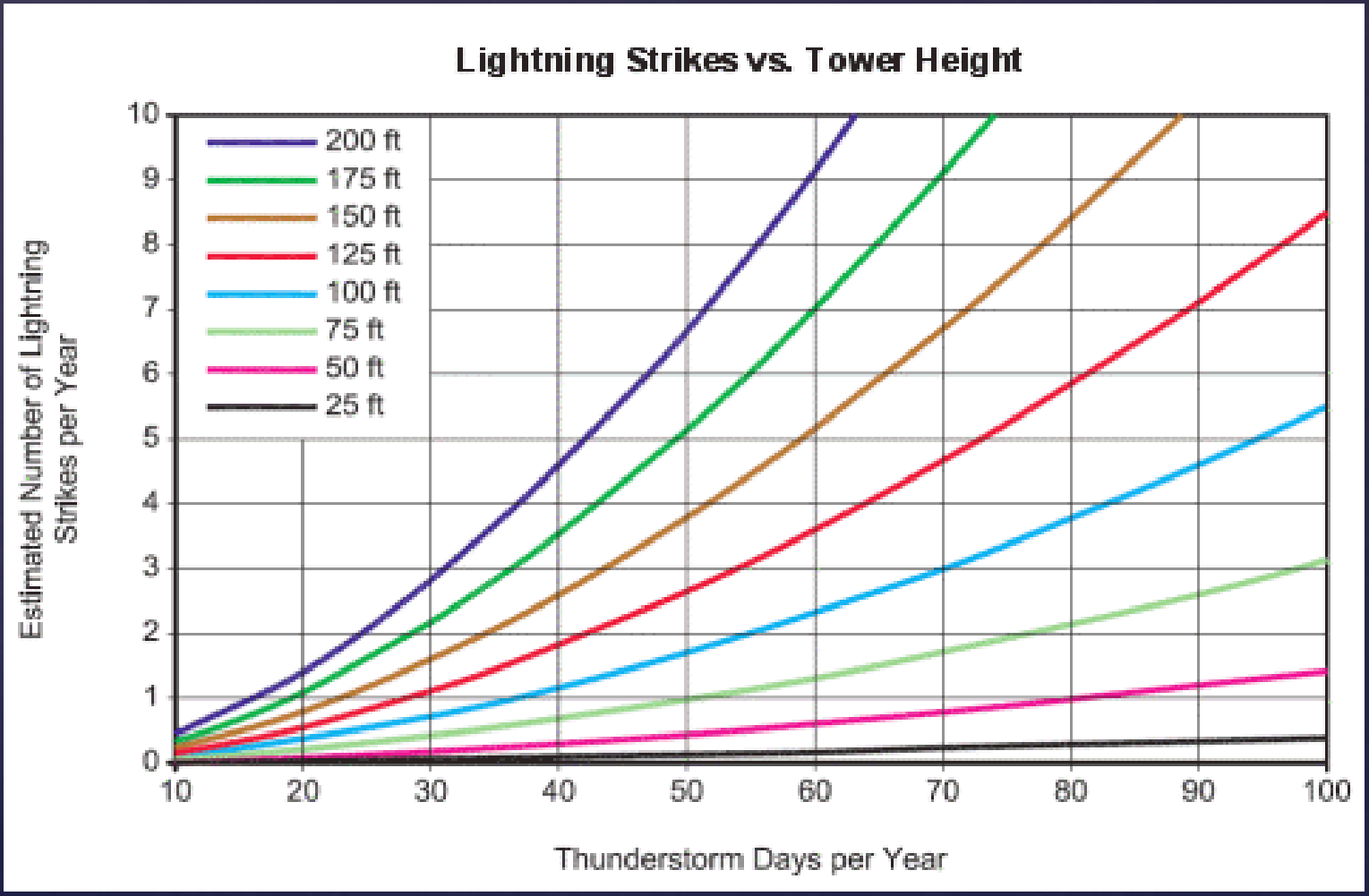

How Much "Stuff" Did I Use?

25 ground rods (8 ft.)

360 feet #4 solid copper wire

25 Cad Weld one shots

3 HLP pipe clamps (CPC1/1.25)

Some of the Toys I Used

How To Improvise When You Can't Reach the Target

- Tower ground rings **shall** be installed at least 2 ft. from the tower foundation (ANSI T1.334-2002, section 5.3.1).
- If 8 ft. ground rods are installed along the ground rings, they **shall** be connected to the ground ring conductor at 10 ft. to 15 ft. intervals (ANSI T1.334-2002), unless otherwise specified.
- If longer ground rods are used, a larger separation proportional to the increase in rod length may be used.
- Ground rods **shall** be placed a minimum of one rod length apart from one another along the ground rings (ANSI T1.313-2003, figure 3(a)).
- Ground rods **shall not** be separated from an adjacent ground rod along the ground ring by more than the sum of their respective lengths. (MIL-HDBK-419A).

From Motorola R56 Standards

How I did it
(from power to tower abt. 140 ft.)

A Little Info on Radials

The copper radials should be buried at least 8″ and preferably 18″ or more underground. A radial in wet soil will work better than the same radial in dry soil. There is also a maximum length where the radial's impedance will prevent any additional electrical charge from traveling further down the line. Short radials do not work very well either, because of the same charge saturation problem mentioned before. A good radial is at least 50 feet, and no more than 75 feet long. If a radial comes within 4 feet of a metal object, that object should be electrically connected to the radial. More radials is certainly better, but after 4 radials one enters the domain of diminishing returns. Keep in mind that radials do not need to go in a straight line. Gradual bends around obstacles or to follow the terrain are fine.

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Exothermic Welds

Joints between copper radials and copper clad rods should be made by exothermic welds or by using joint compounds in high compression clamps. Solder connections, even torched silver solder connections will not last as long as the above. An exothermic weld is created when a graphite mold around the connection is filled with copper oxide and aluminum powders. An additional starter powder ignites the exothermic process. The resultant molten copper is deposited into the lower mold cavity where it burns away any oxides and creates a larger fused connection. The larger cross sectional bond decreases the resistance and increases the surface area, reducing the inductance of the joint. Since the materials are all the same, the connection will last as long as the rest of the grounding material.

PolyPhaser tech document 1016

When Cad Welds go bad

4 Way At Tower Base

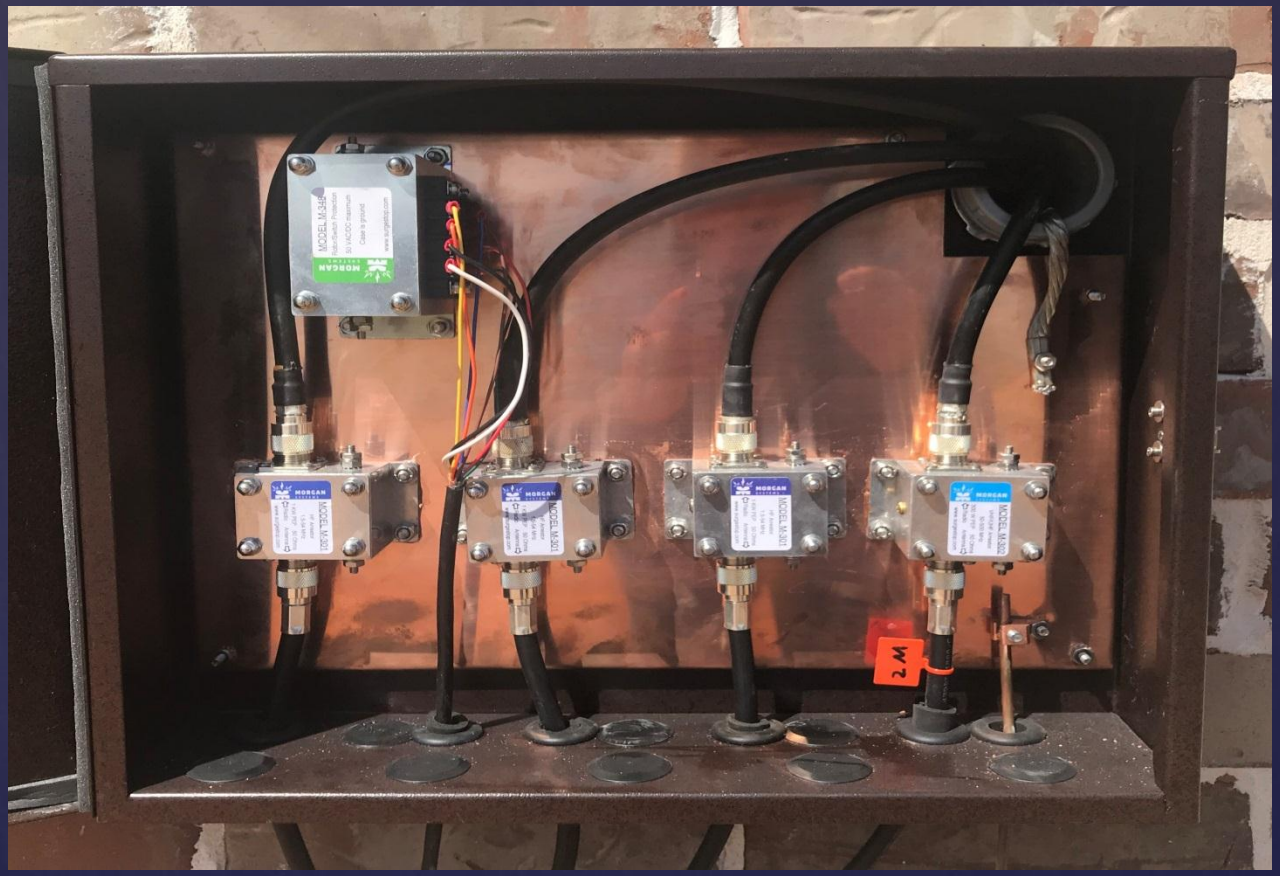
How I Grounded My Mast

Clamps from tower to ground

All 3 legs are bonded because current can flow down each leg. Current could flow down one leg only giving a 33% chance of guessing right if only one leg is grounded

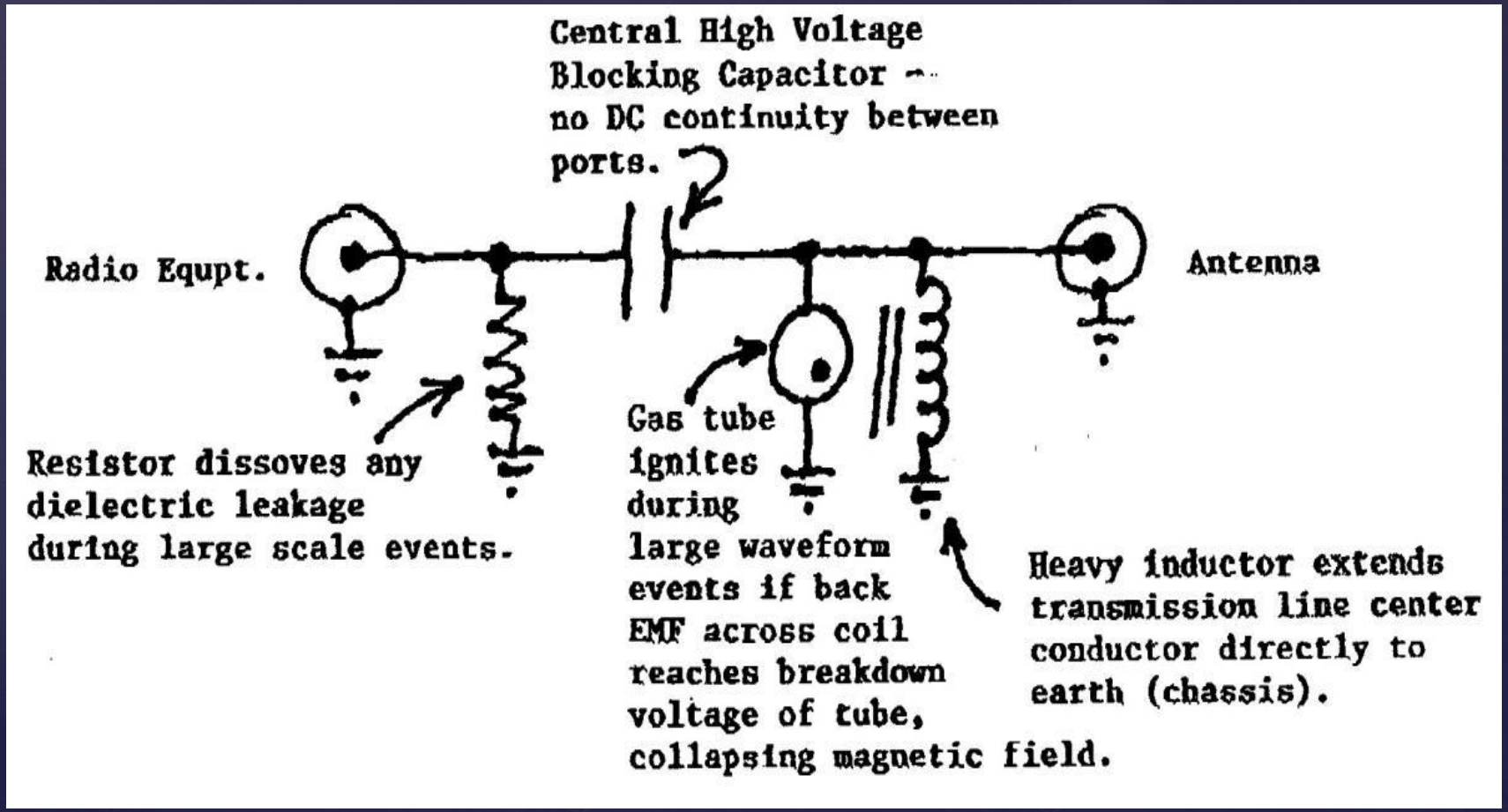
A KF7P Lightning Arrestor Panel

Interior Showing Lightning Arrestors

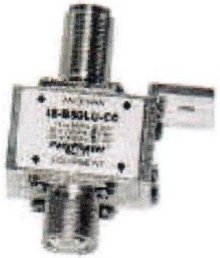


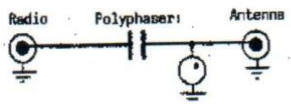
The Lightning Arrestors I Used

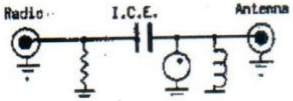
(Industrial Communications Engineers)

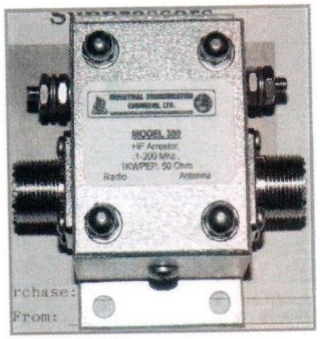


Polyphaser vs ICE







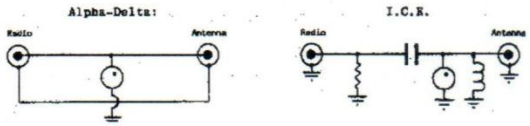


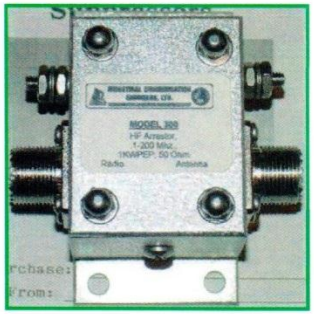
Polyphaser relies on Coax Inductance to fire Arc Plug
Polyphaser blocks DC and impedes low frequency impulse.

Many Polyphaser units are narrow band due to Capacitor.

ICE has Inductor to bleed static and absorb an impulse.
ICE uses Arc Plug to collapse Inductor magnetic field. Lower Dissipation.
ICE has resistor at output to bleed voltage from Capacitor and protect Radio.

Alpha Delta vs Ind. Comm. Engrs.





Alpha Delta Relies on Coax Inductance to cause voltage to fire Arc Plug.
AD provides no protection to a grounded switch or radio front end.
AD Arc Plug must drain all the strike energy. Rated about 1W.
AD will not drain static electricity from coax. Charge can build.

ICE inductor bleeds static and absorbs impulse.
ICE Arc Plug fires to collapse inductor magnetic field. Less Dissipation.
ICE Capacitor blocks DC and impedes lower frequencies.
ICE Resistor protects radio and provides a path to discharge Capacitor.

From the PolyPhaser White Papers

The most effective type of lightning arrestor is “dc blocked.” There is no center conductor continuity from connector pin to pin. This internal capacitive coupling prevents the sharing of low-frequency surge current with equipment and limits the throughput energy to an amount that can be coupled only by the electrostatic field in the capacitor. This allows the dc blocked gas tube type “Impulse Suppressor” to fire as the voltage reaches the turn-on threshold. PolyPhaser has given considerable attention to the gas tube design to insure that, when transmitting, the RF power will not keep alive the gas in the tube after a strike. Many other protectors, even those licensed by our patent, use a type of gas tube that will not extinguish properly. The transmitted energy continues to excite the tube which becomes a broadband noise generator and will burn up unless transmit power ceases. Some arrestors use an internal grounding coil designed to drain any coax voltage build-up. (There would not be any, if a dc grounded antenna were used.) The coil is in parallel with the gas tube and does not help filter higher frequency components like antenna ringing, etc. This type of design uses a simple gas tube and has the gas tube extinguishing problem.

Type II surge protection not only helps protect radio equipment but everything else in the house. The 2020 NEC requires all new installs and upgrades to have this. Texas has adopted the 2020 NEC.

Why Bond Everything???

Protection of equipment & persons from the hazards of lightning discharges

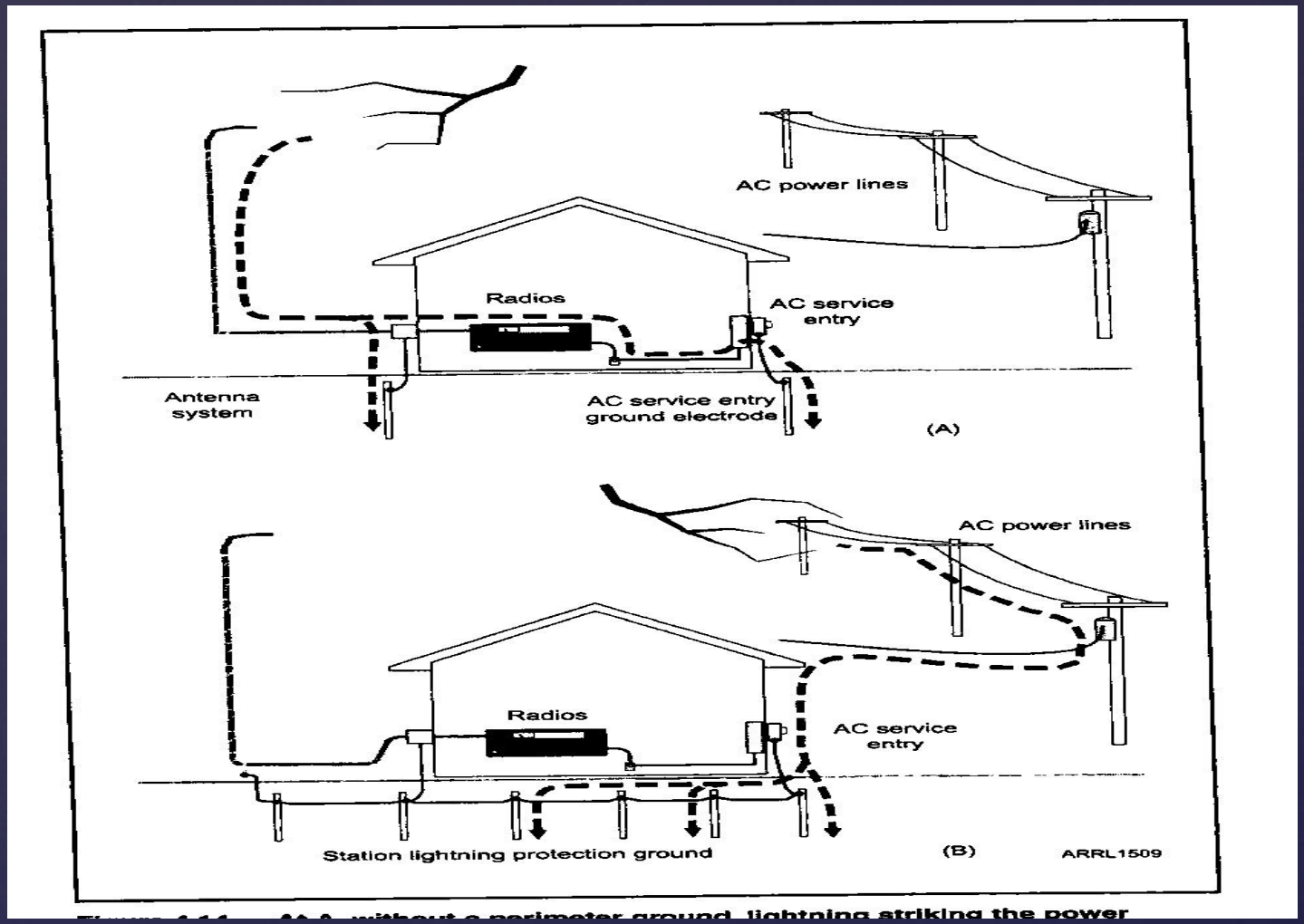
Establishment of fault current return paths

Establishment of homogenous, stable paths for signal currents

Minimize rf potentials on enclosures and housings

Protection from shock hazards arising from accidental power grounds

Prevention of static charge accumulation



From "Grounding and Bonding for the Radio Amateur" ARRL Publication

How Captain Video Did It.
(notice no paint removed from meter box)

How To Route Coax To The Station

- The more coax lines there are, the more the current is divided and the less there will be on any given line.
- The lower the coax is grounded to the tower, the less shield current there will be on each coax line.
- The lower the inductance path to ground from the MGB or bulkhead, the less shield current will enter the building.
- The farther the tower is spaced from the MGB/ building entrance, the more inductance the coax line(s) will have, and the less current will be on the line(s). We do not recommend adding loops to increase inductance. They can couple more energy like a transformer (depending on orientation to the tower) instead of reducing it.

Coax Shield Ground at Tower Base

Questions?

Comments?