When Lightning Strikes

Grounding for Amateur Radio Stations

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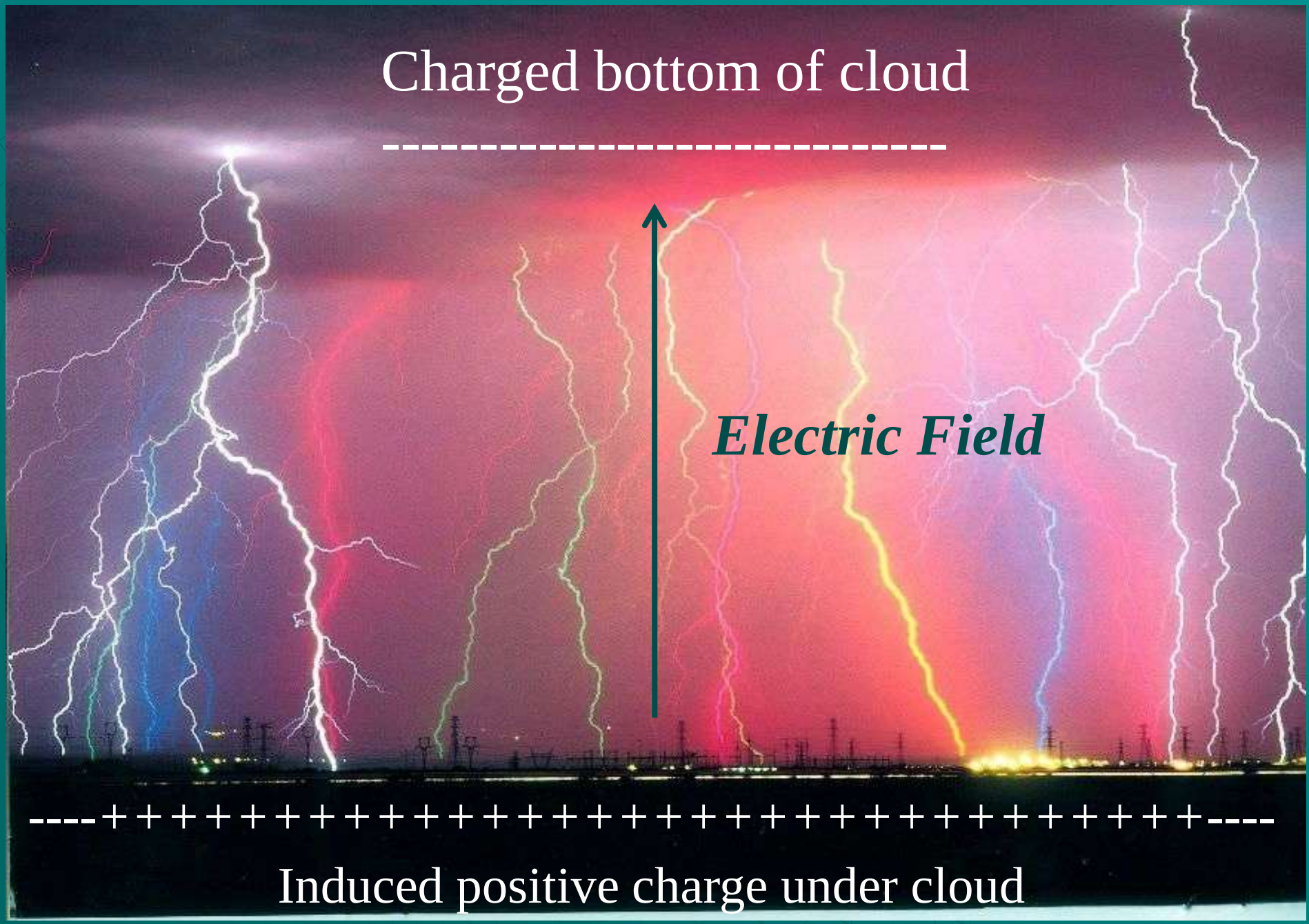

Charged bottom of cloud

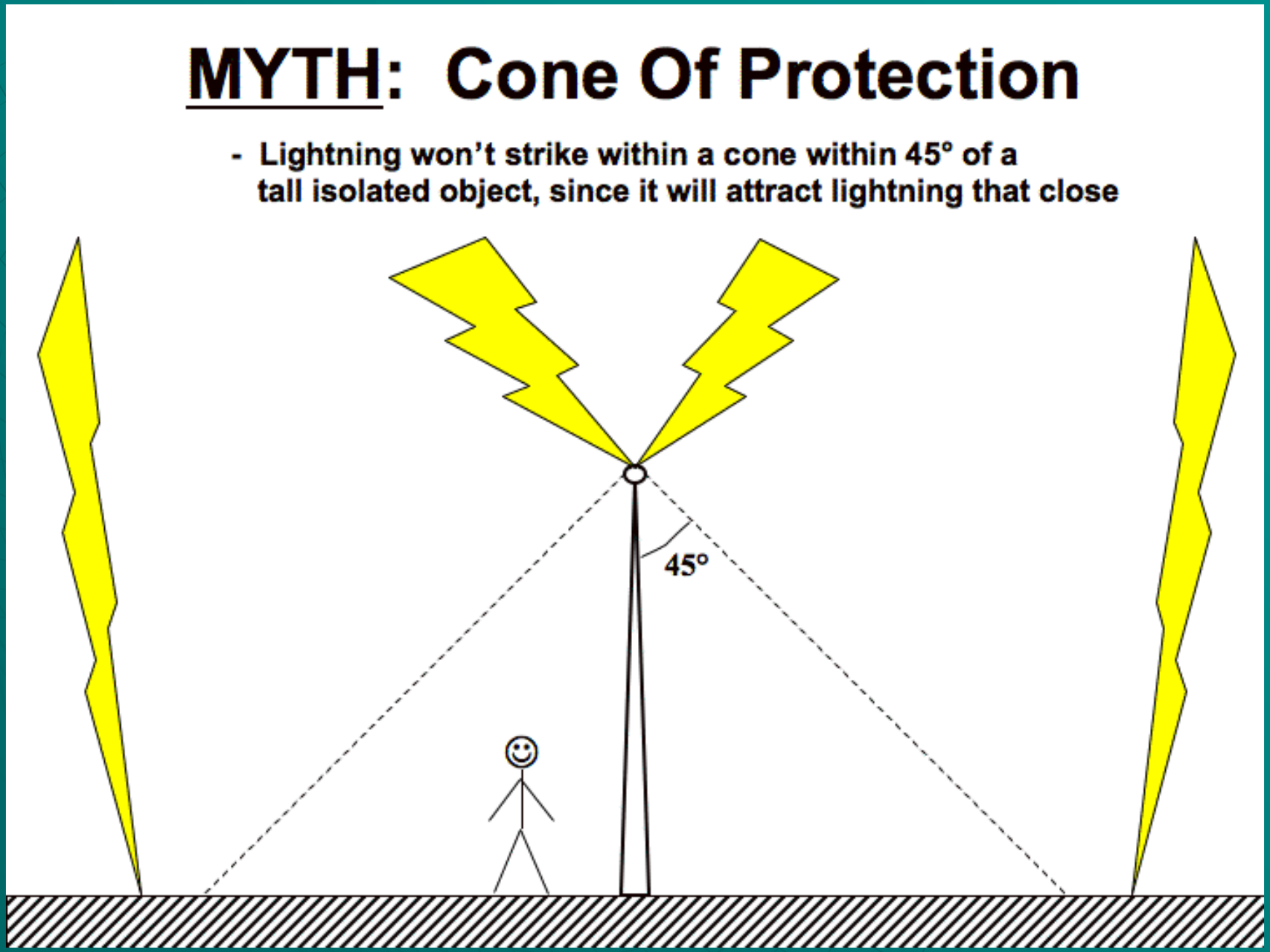
Electric Field
----++----
Induced positive charge under cloud

Typical Characteristics of Lightning Strikes

- Length of bolt: 300 meters to 1600 meters
- Voltage difference: 10^6 to 10^9 volts
- Average current of main strike: 40,000 amps
- Return Strikes: 10,000 to 15,000 amps
- Rise time: 1.8 μs
- Decay time: 50 μs
- Air breakdown: 3 x 10^6 volts/meter (3000 volts/mm)

Cone of Protection Myth

*The following drawings depict why the so-called "cone of protection" from lightning afforded by a nearby tall object is fallacious.**



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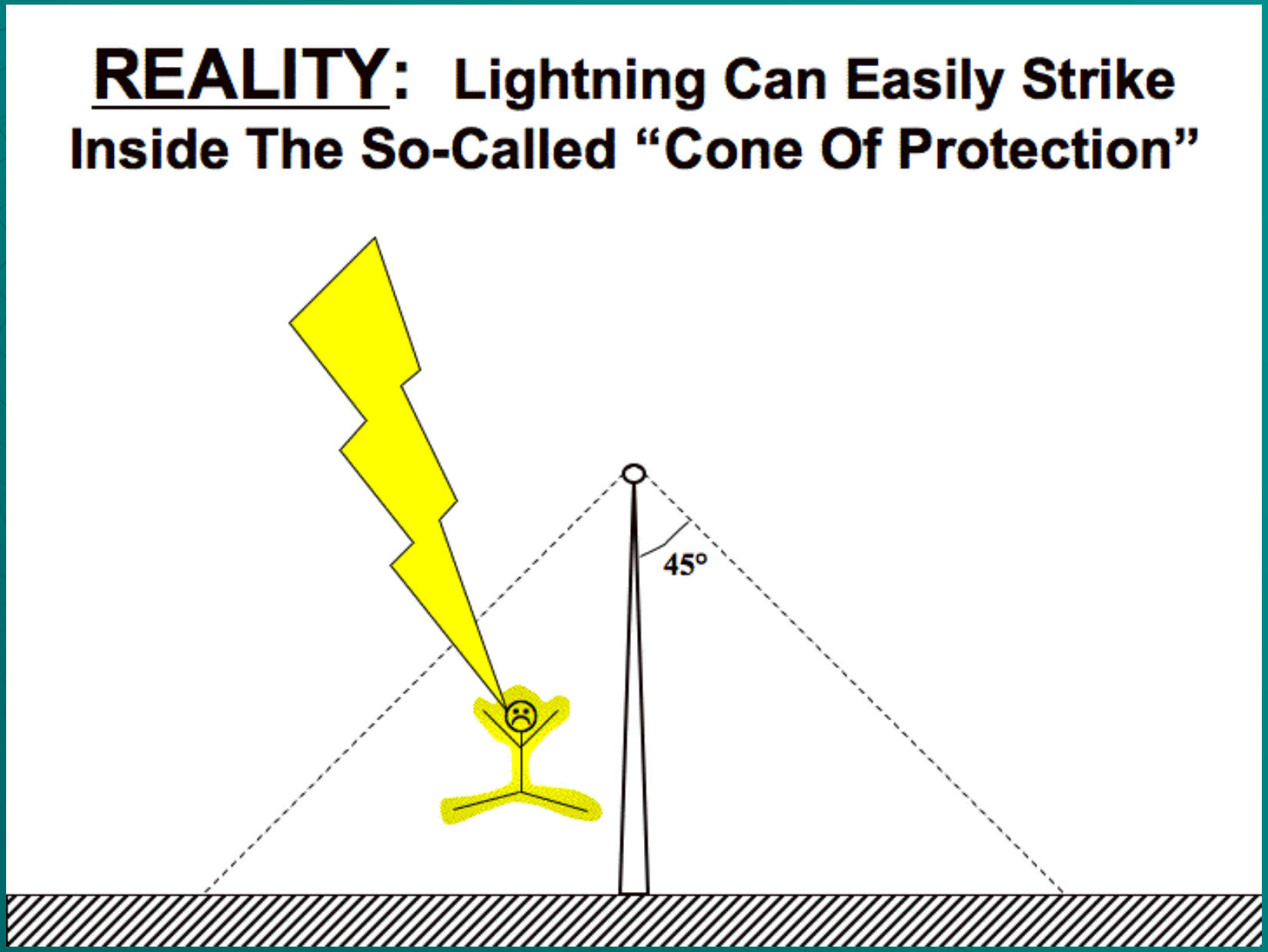

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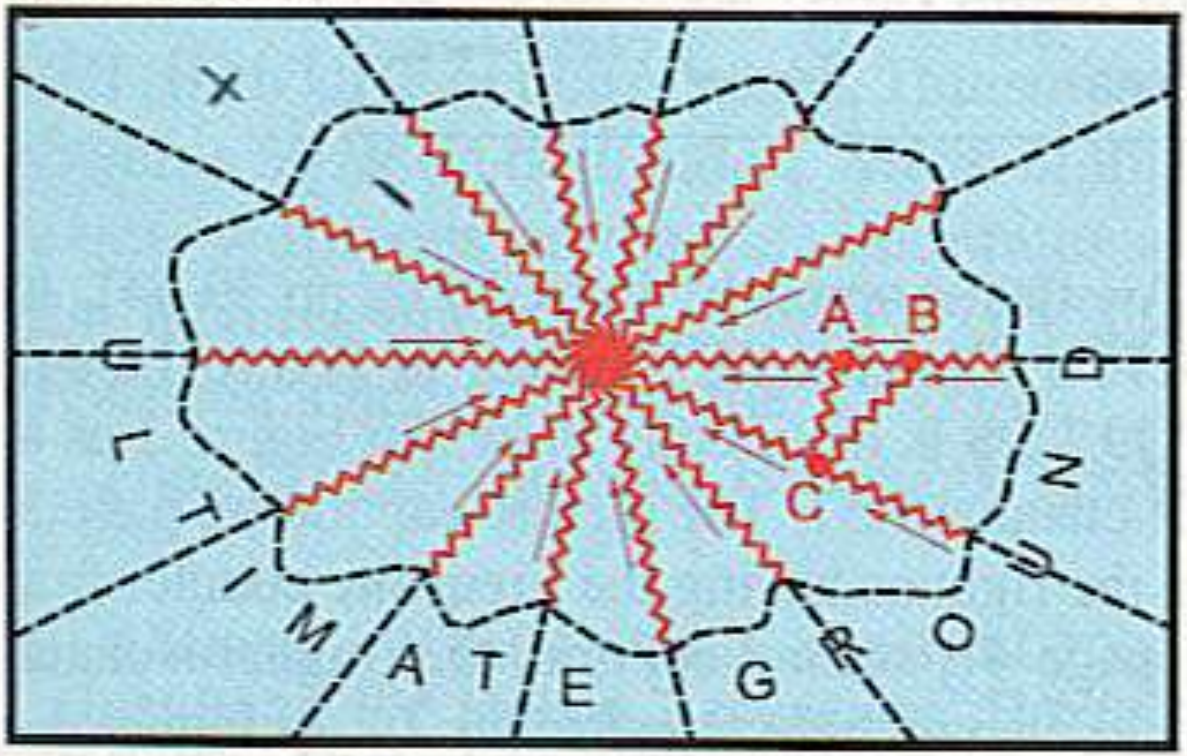
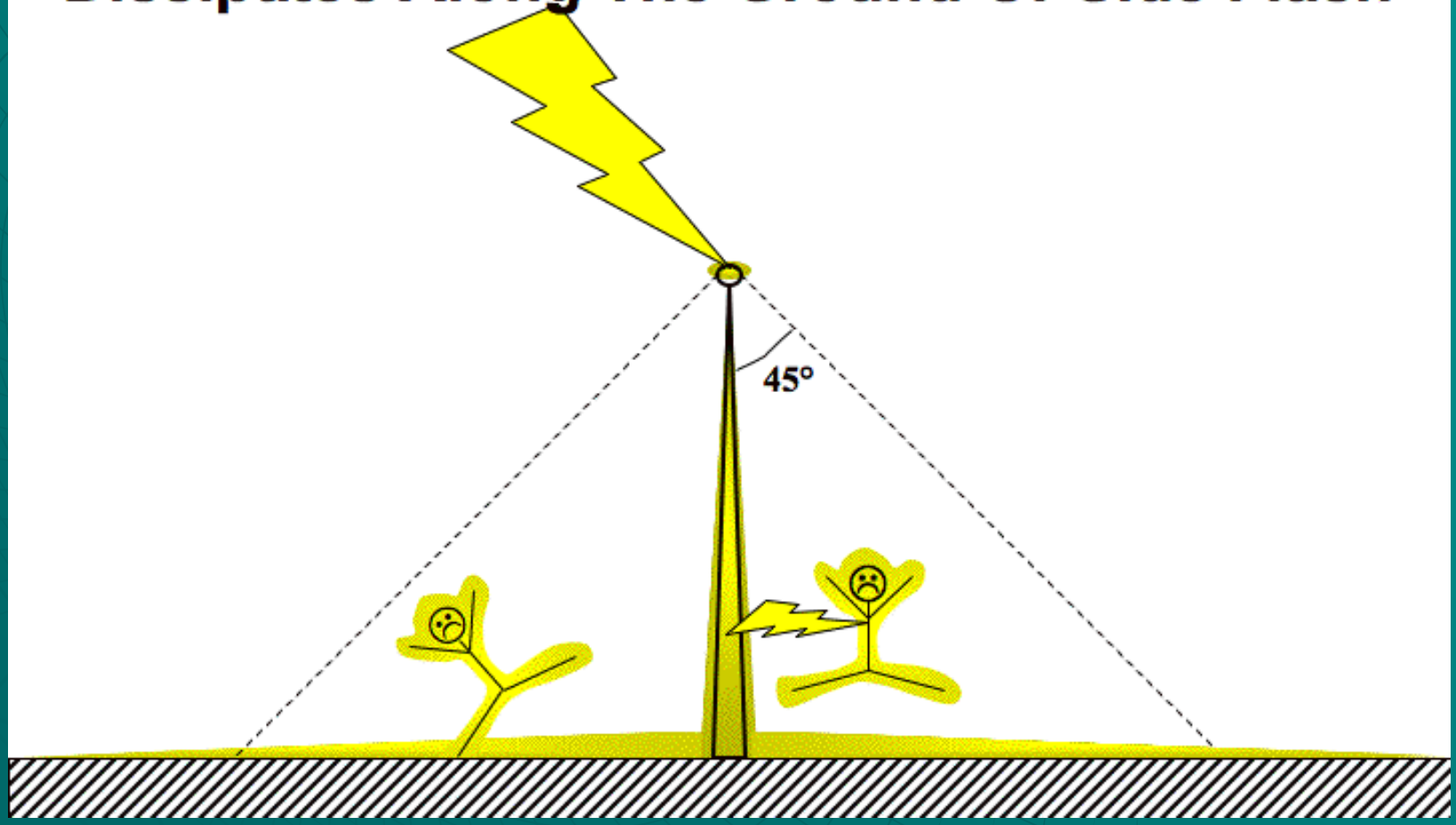


Figure 3 — Below ground earth currents of a lightning strike as viewed from above. The potential difference between points A and B, and either and C, can result in dangerous voltages between nearby points. This is often the cause of fatalities of cows or golfers that gather under a tree during a storm.

REALITY (continued): Even If Lightning Strikes The Object, You're Still In Danger As It Dissipates Along The Ground Or Side Flash



In-House Surges due to nearby strikes

Electromagnetic induction from nearby strikes can produce large voltage/current surges in residential wiring.

Voltage peaks on the order of 6000 volts and currents on the order of 3000 amps with rise time of 1-2µs may occur.

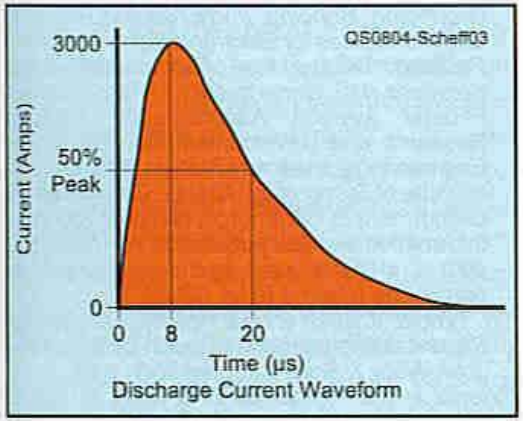


Figure 3 — Waveshapes representing a typical resultant surge that might appear in the wiring at a load center panel.

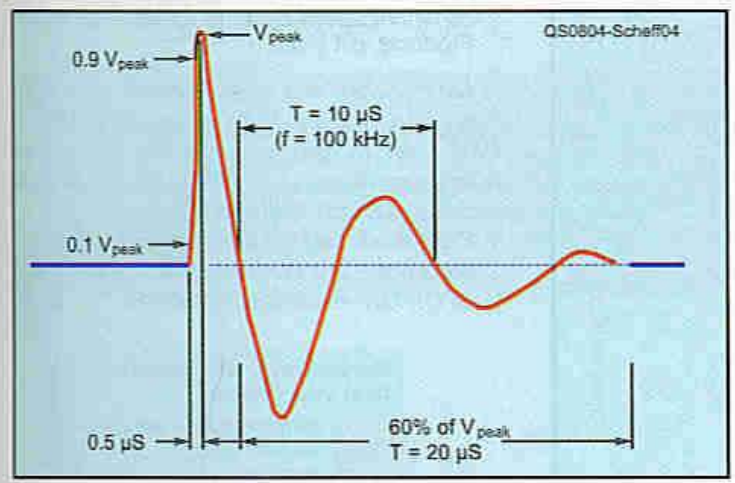
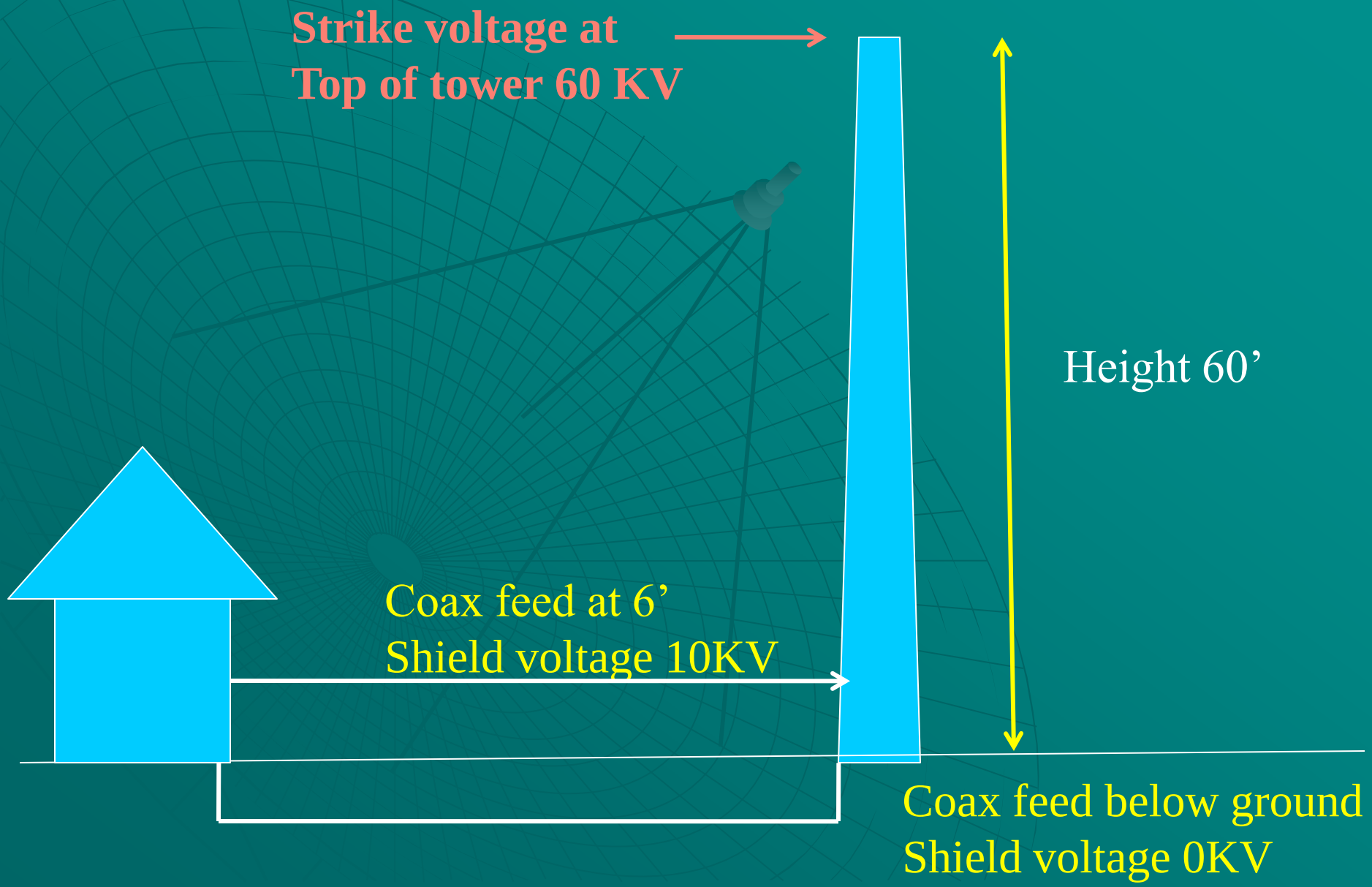
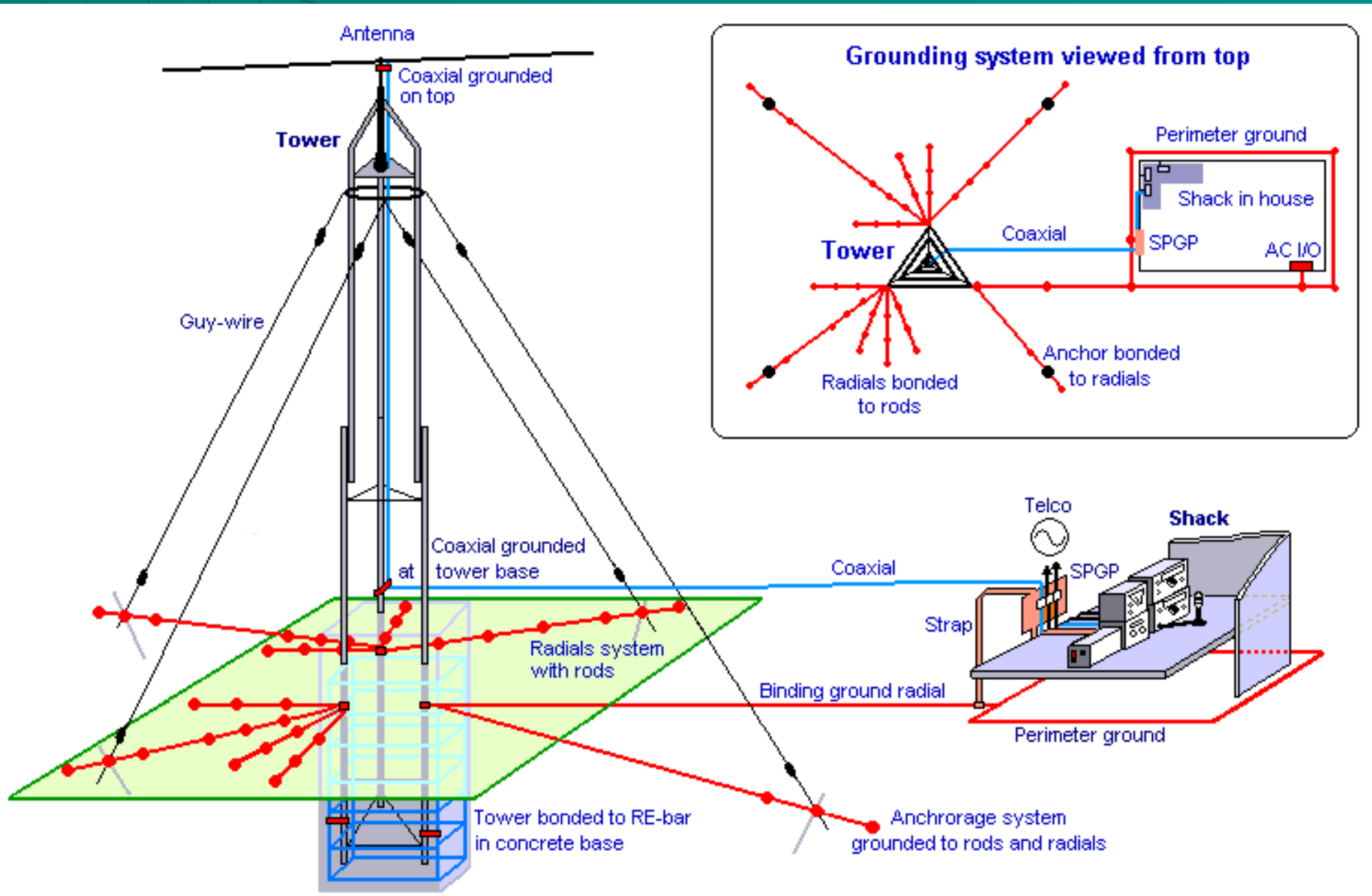


Figure 4 — The 0 V axis represents the instantaneous voltage level of 60 Hz ac waveform upon which this surge "rides." The quantity of energy in a surge is proportional to the area under the curve.

Coax Line Voltage Surges



Single Point Ground System (from PolyPhasor



Feed Lines and Grounding

- Coax lines to be in underground conduit rather than going overhead.
- In-line surge protectors on coax and shunt protectors on rotator cable preferably at the base of the tower.
- Ground rods at each tower leg and additional rods spaced at twice their length and all tied together, to a perimeter ground and the AC service ground at entrance panel (service ground).
- Single Point Ground at entry point to shack tied to perimeter ground.
- Feed lines: Ground coax shields at base of tower.

Single point ground plane

A consideration of materials for the ground plane inside the radio room leads to consideration of their respective conductivities.

Material	Resistivity	Conductivity
Silver (Ag)	1.59e-8	6.29e7
Copper (Cu)	1.70e-8	5.89e7
Gold (Au)	2.44e-8	4.10e7
Aluminum (Al)	2.82e-8	3.55e7
Iron (Fe)	10.0e-8	1.00e7

Some Thoughts on Grounding Conductors

EQUATIONS FOR INDUCTANCE OF VARIOUS COPPER CONDUCTORS

- Round Copper Wire $L = 2\ell \{ \ln(4\ell/d) - 1 \} \times 10^{-7}$ μH
- Rectangular Copper Strapping $L = 2\ell \{ \ln[2\ell/(b+c)] + \frac{1}{2} \} \times 10^{-7}$ μH
- Round Copper Tubing $L = 2\ell \{ \ln(2\ell/r) - \frac{3}{4} \} \times 10^{-7}$ μH

L (μH)
ℓ (length in meters)
d (diameter in meters)
b & c (width and thickness resp. in meters)
r (radius in meters)

Calculated Inductances L(μH)

Conductor	Inductance	Cross-sect. Area
# 10 copper wire:	1.27 μH/m	
•# 6 copper wire:	1.18 μH/m	0.021 inch^2
•1/2" copper water pipe	0.91 μH/m	0.307 inch^2
•2" x 0.011" copper strap:	0.84 μH/m	0.022 inch2
•3/4" inch copper water pipe	0.70 μH/m	0.600 inch^2

SURFACE AREA MATTERS AT RF FREQUENCIES

Conductor	Circumference /Width	
•# 10 copper wire:	0.32 inches	8.12 mm
•# 6 copper wire:	0.51 inches	13 mm
•1/2 inch copper water pipe:	1.96 inches	49.8 mm
•2 inch x 0.011 inch copper strap:	4 inches	101.6 mm
•3/4 inch copper water pipe:	2.36 inches	59.9 mm

Effect of Surge Currents on Conductors

Ohm's Law for Inductances

$V = I X_L = I 2\pi f L = I 2 \pi (1/T) L$

- Suppose you have a 10 meter (32') copper conductor:
- What is the voltage difference between the ends with a surge current of 200 amps with a rise time of 2 μs.

#6 Copper wire: $\Delta V = 754$ volts

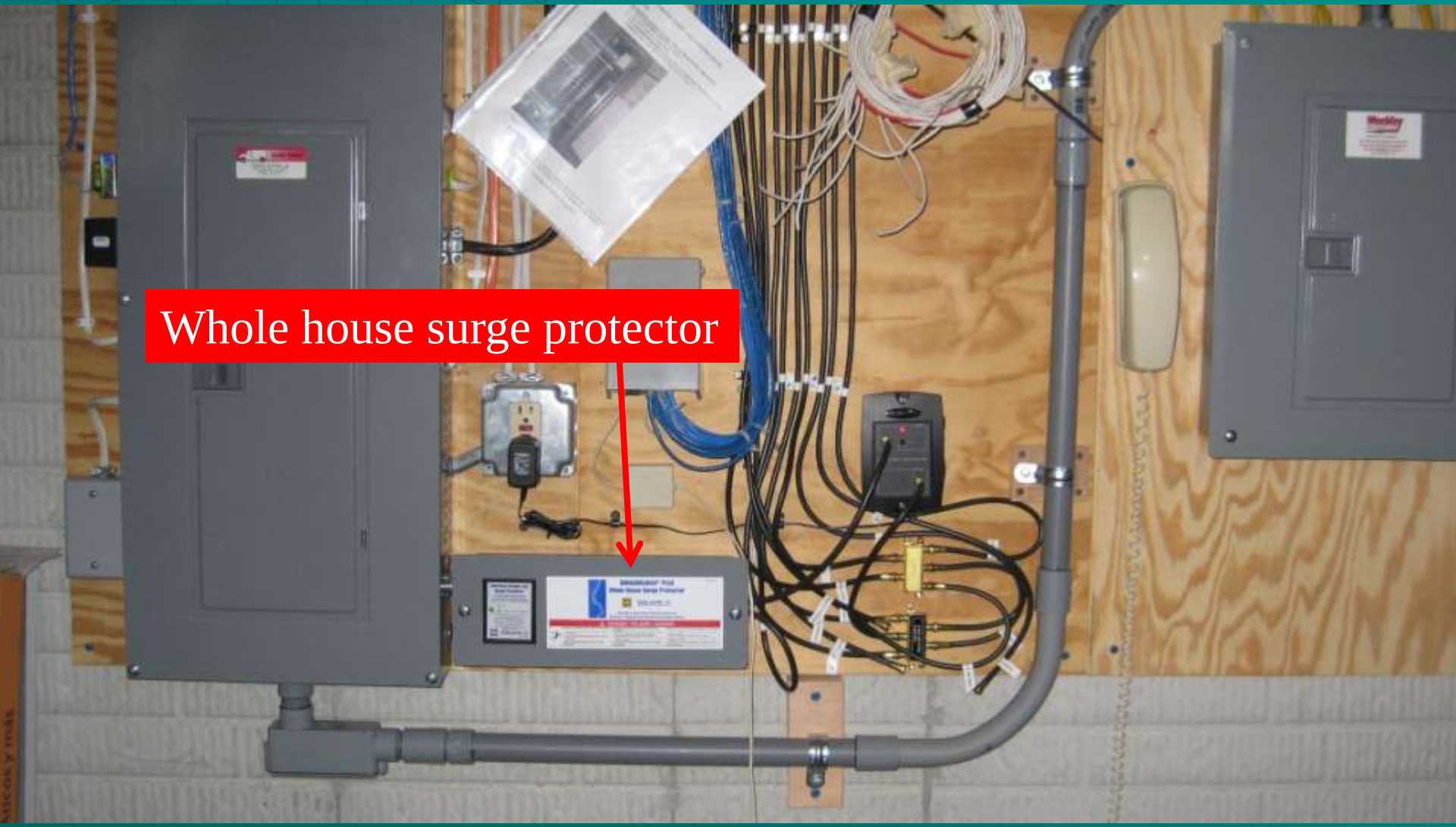
2" Copper strap: $\Delta V = 528$ volts

NOTE: However, in both cases the DC IR voltage difference is $\Delta V = IR = 2.6$ volts, much smaller than the induced voltage...essentially negligible.

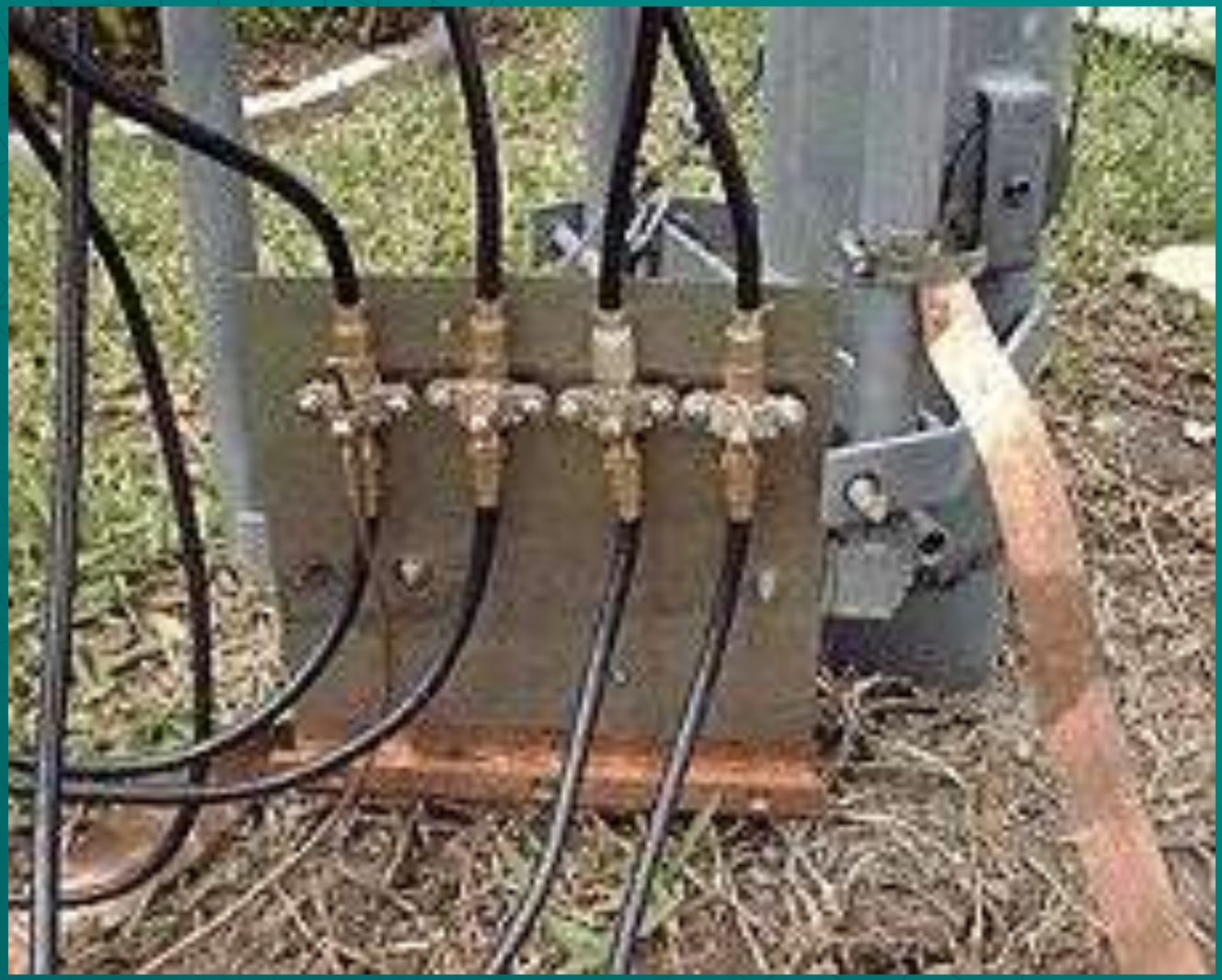
Lightning Protection

- Whole house surge protectors at the entrance panel.
- Surge protectors at appliance locations (Radio Room)
- Single point ground connected to service ground at entrance panel routed outside of the residence.
- Surge protectors on all antenna lead-ins.
- Towers grounded and connected to the single point Ground.
- Coax shields grounded to tower legs as low as Possible.

Whole House Surge Protector

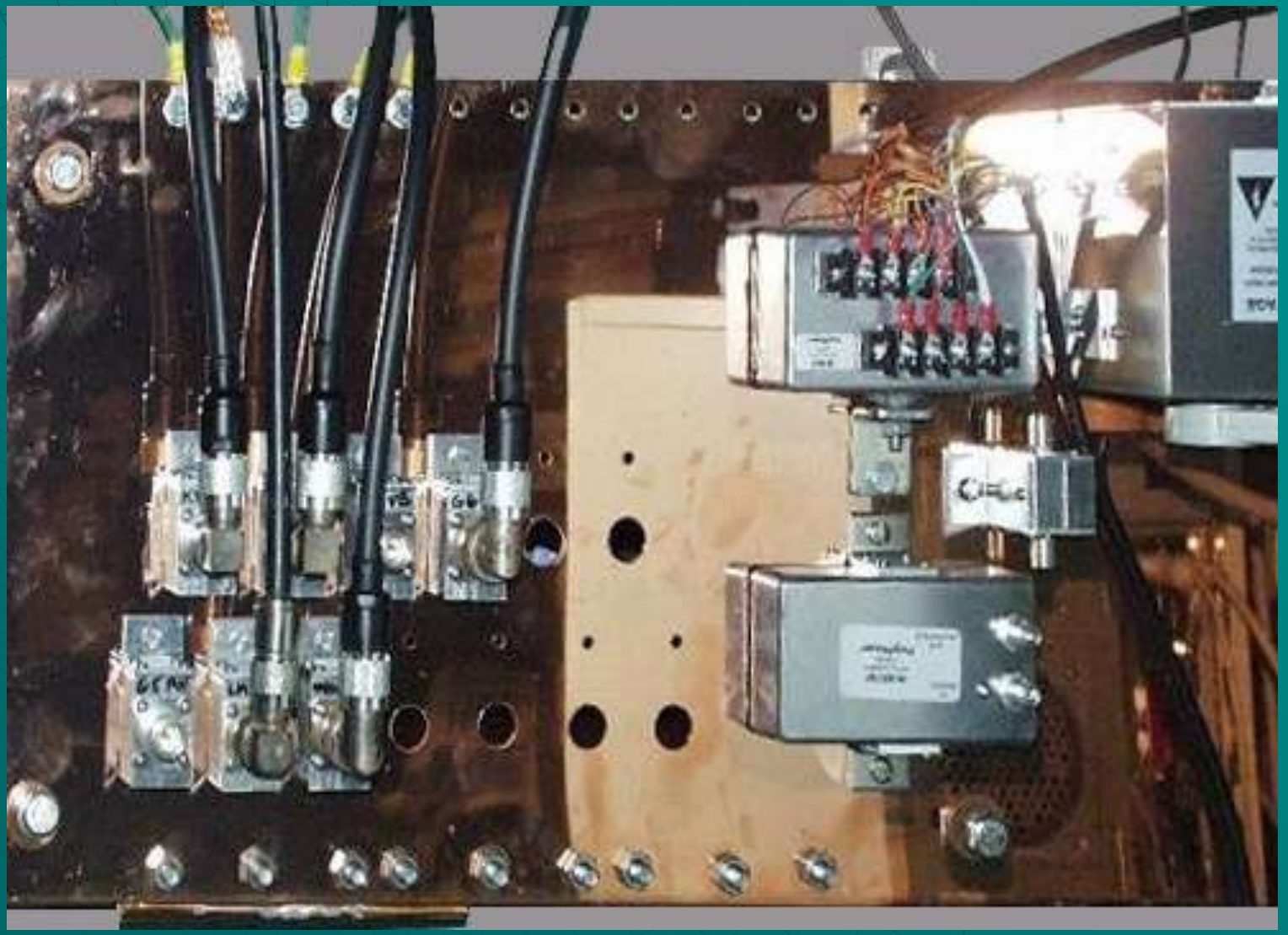


Surge protectors at base of tower, note ground straps to ground rods (KC9CS)



ICE installation for three SteppIR Antennas

Single point ground inside radio room (K5GS)



The Radio Room

The Good News for most of us…

Our area experiences around 45 Thunderstorm days per year.

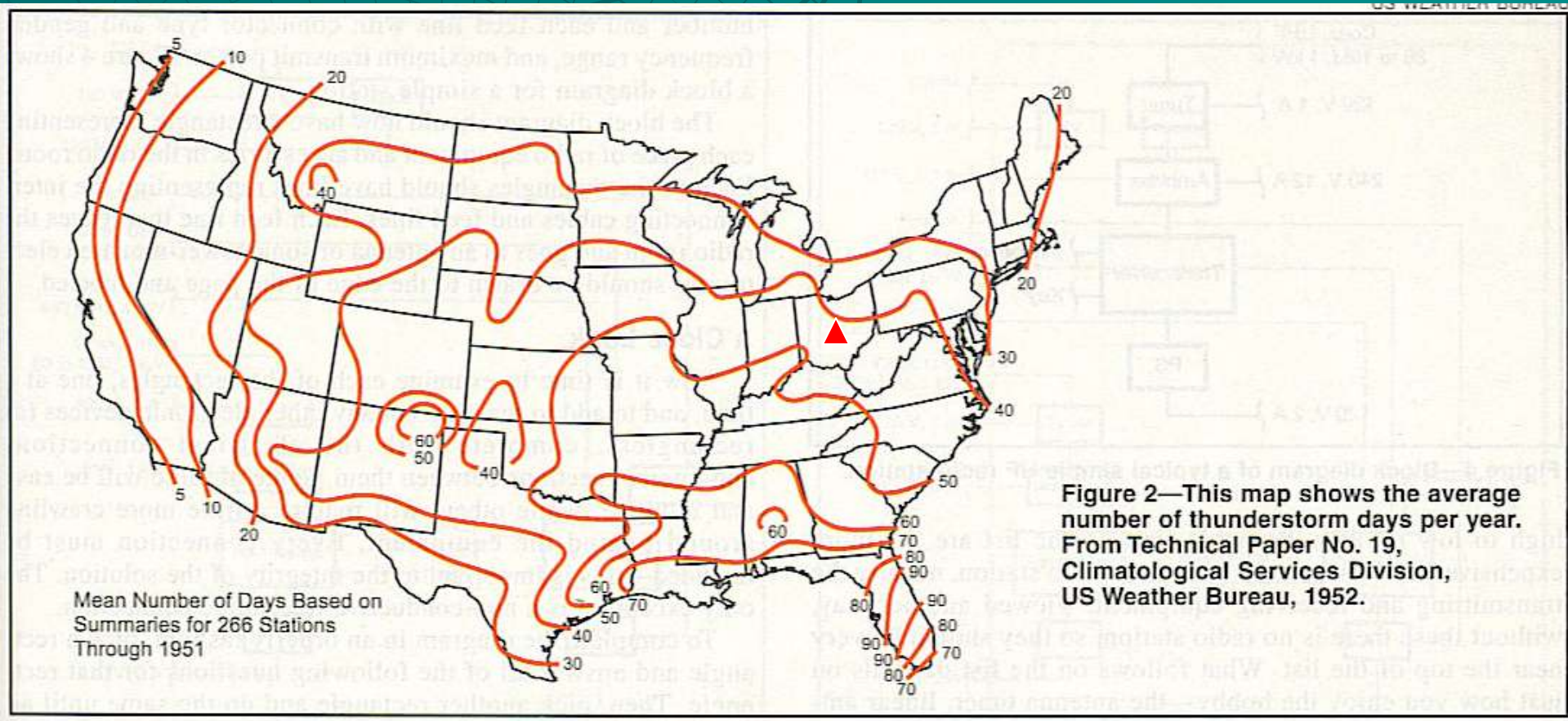


Figure 2—This map shows the average number of thunderstorm days per year. From Technical Paper No. 19, Climatological Services Division, US Weather Bureau, 1952.

Estimated number of lightning Strikes for a given tower height per year. A 50’ tower, indicated by the red triangle below would expect to receive one strike in a three year period.

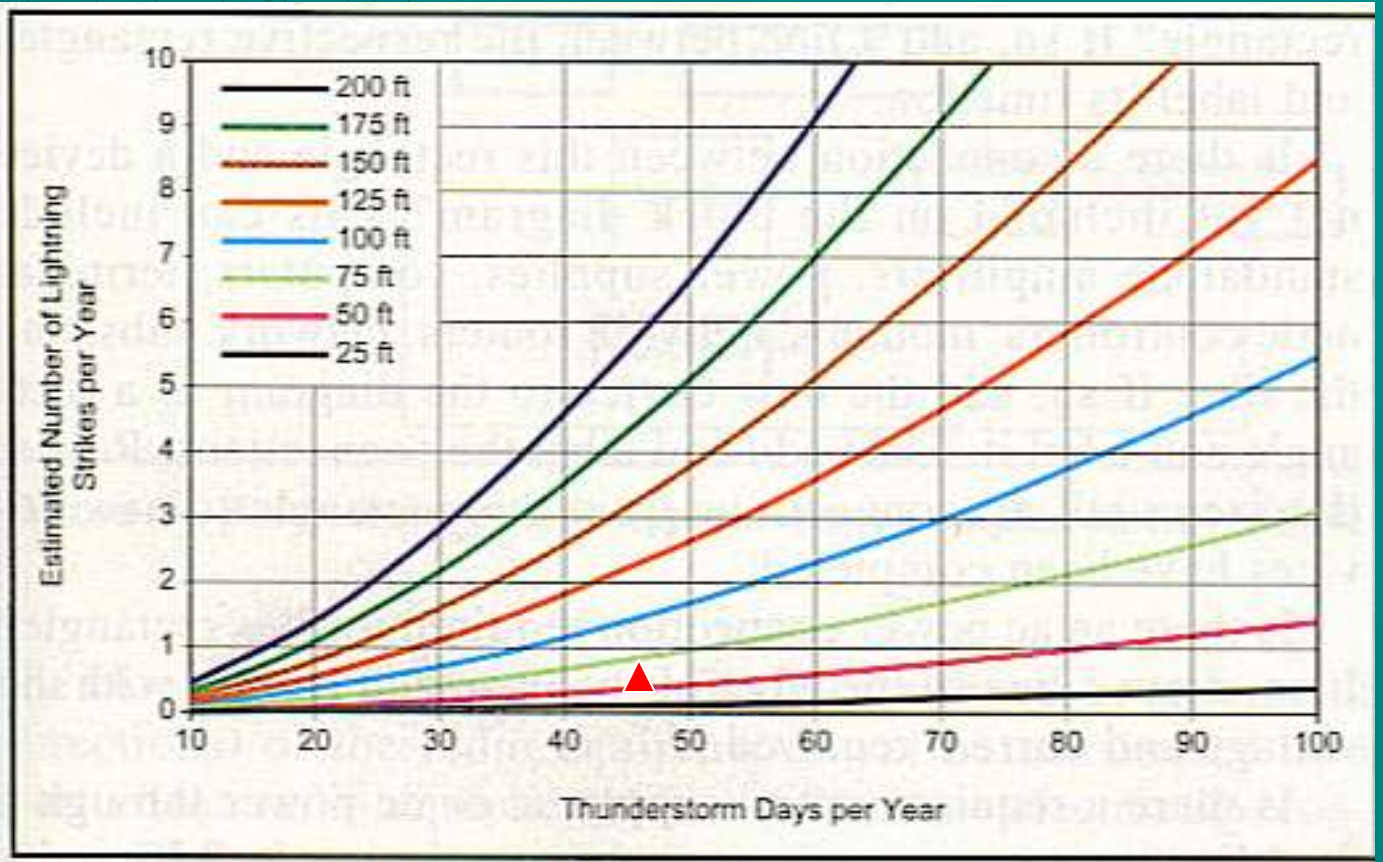


Figure 3—Estimated number of lightning strikes per year based on the number of thunderstorm days in your area and the height of your antenna. Based on information from *Living with Lightning*, Seminar Notes #ECP-826B Version F, GE Mobile Radio Technical Training, © GE 1985.

Final Caveat!

- In my opinion, no lightning protection system is full proof, especially for a direct hit although some well designed sites experience multiple hits without damage.
- When I turn off the radio equipment I do the following.
  - Unplug equipment from AC mains.
  - Ground all antennas. It is best to do it outside to keep the effects of a lighting strike outside the station.
- However, if one forgets, and if you have followed the "rules," a near-by strike may be mitigated by your lightning protection system.

Helpful References

•Scheff, W4QEJ; *Lightning: Understanding it or Suffer the Consequences—Part1*, *QST* Feb. 2008, 92, pp 40-44

•Scheff, W4QEJ; *Lightning: Understanding it or Suffer the Consequences—Part2*, *QST,* April 2008, 92, pp 30-34

•Block, KB2UYT; *Lightning Protection for the Amateur Radio Station—Part 1*, *QST*, June 2002, 86, pp 56-59

•Block, KB2UYT; *Lightning Protection for the Amateur Radio Station—Part 2*, *QST*, July 2002, 86, pp 48-52

•Block, KB2UYT; *Lightning Protection for the Amateur Radio Station—Part 3*, *QST*, August 2002, 86, pp 53-55

•See also web sites, www.polyphaser.com, www.wrblock.com, www.dxengineering.com, http://www.astrosurf.com/luxorion/qsl-lightning-protection3.htm and others.