



Lightning!

Protecting your Equipment

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ANT 3

ANT 2

ANT 1

CONTROL
CO. '77 '78

RON



Disclosure

Have no relevant financial relationships or conflicts of interest with commercial interests related directly or indirectly to this educational activity.





Lightning and grounding



◆ Part 1

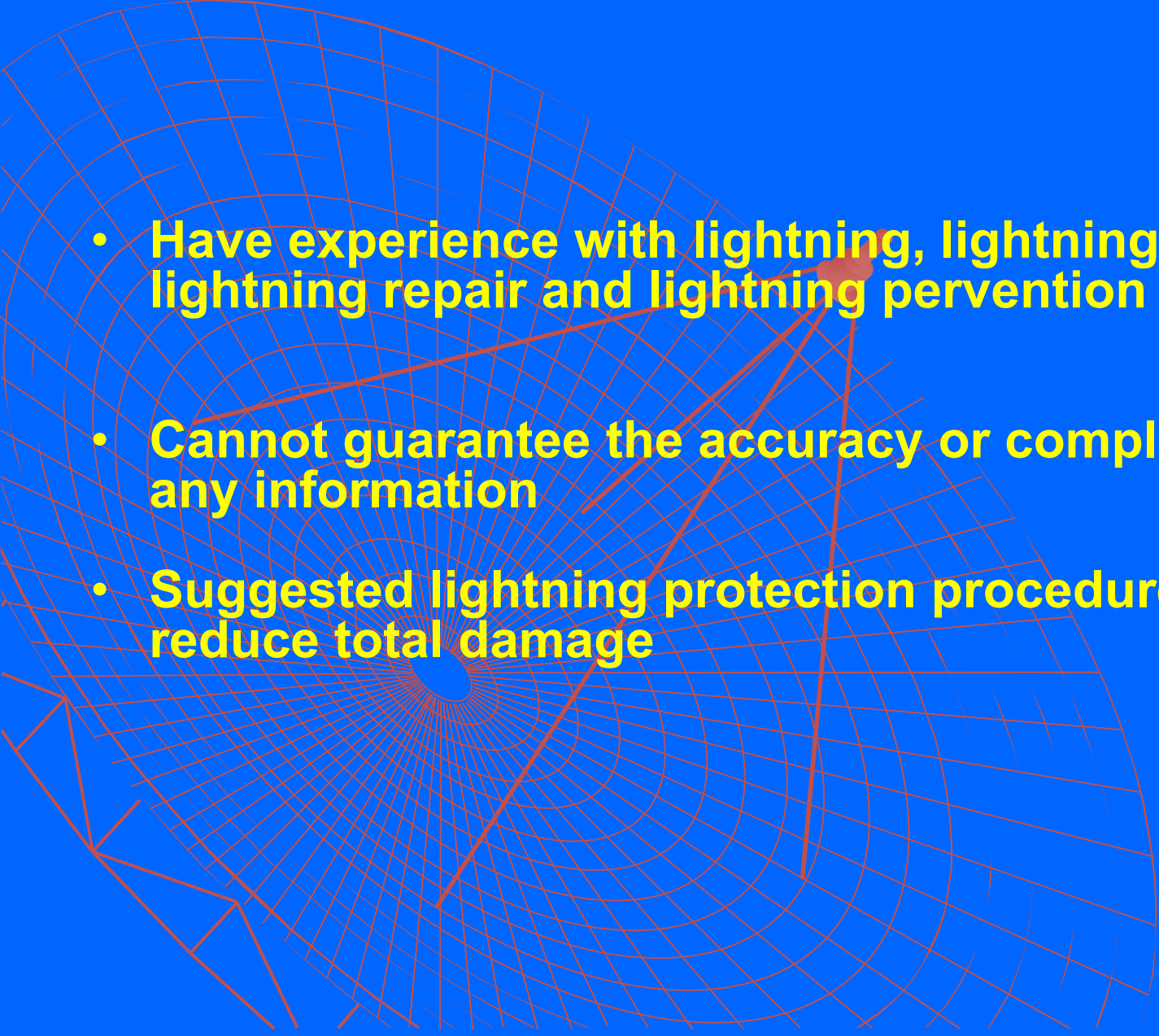
- Lightning - the what, when, where and how
- Lightning effects on a human

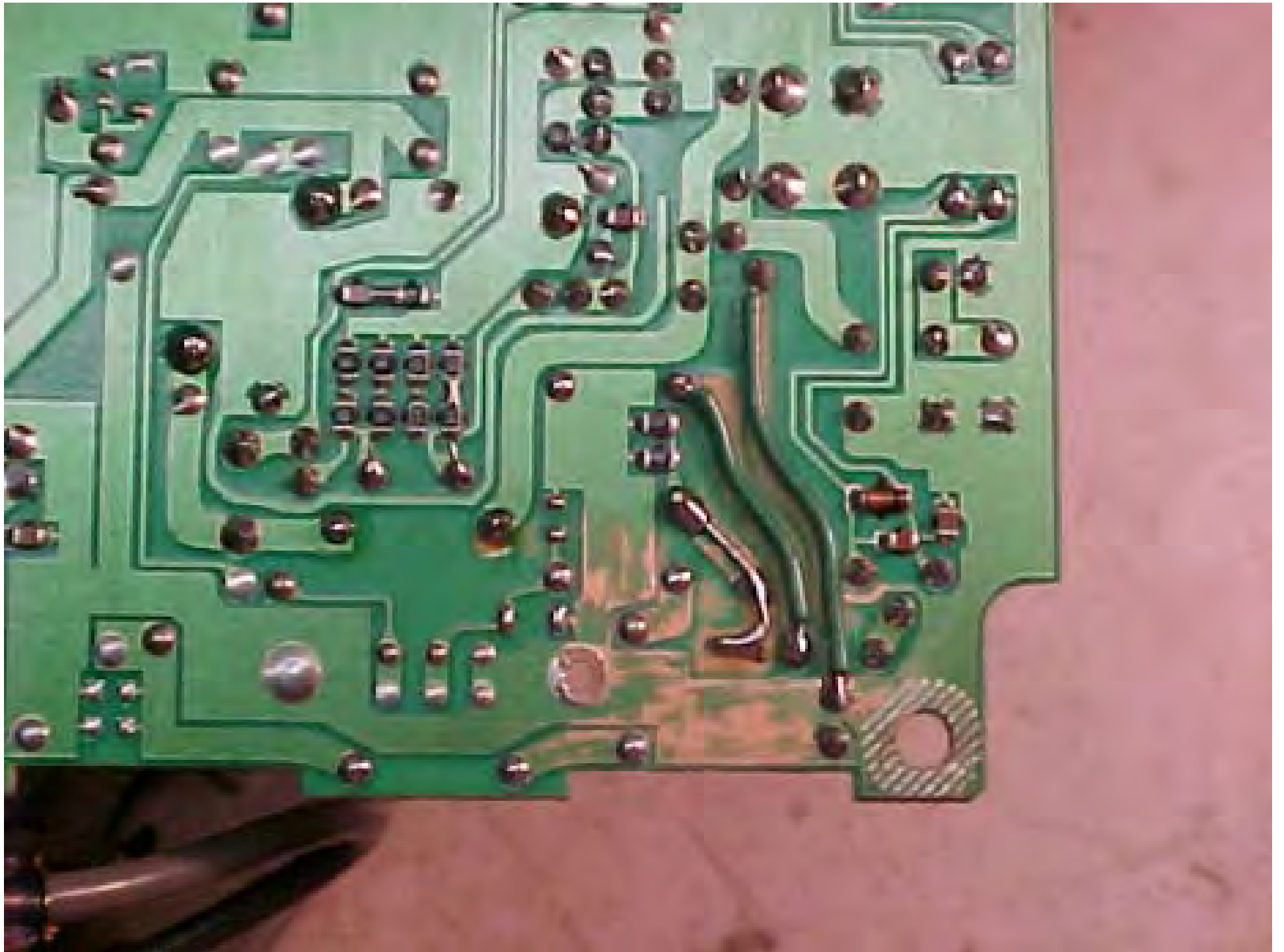
◆ Part 2

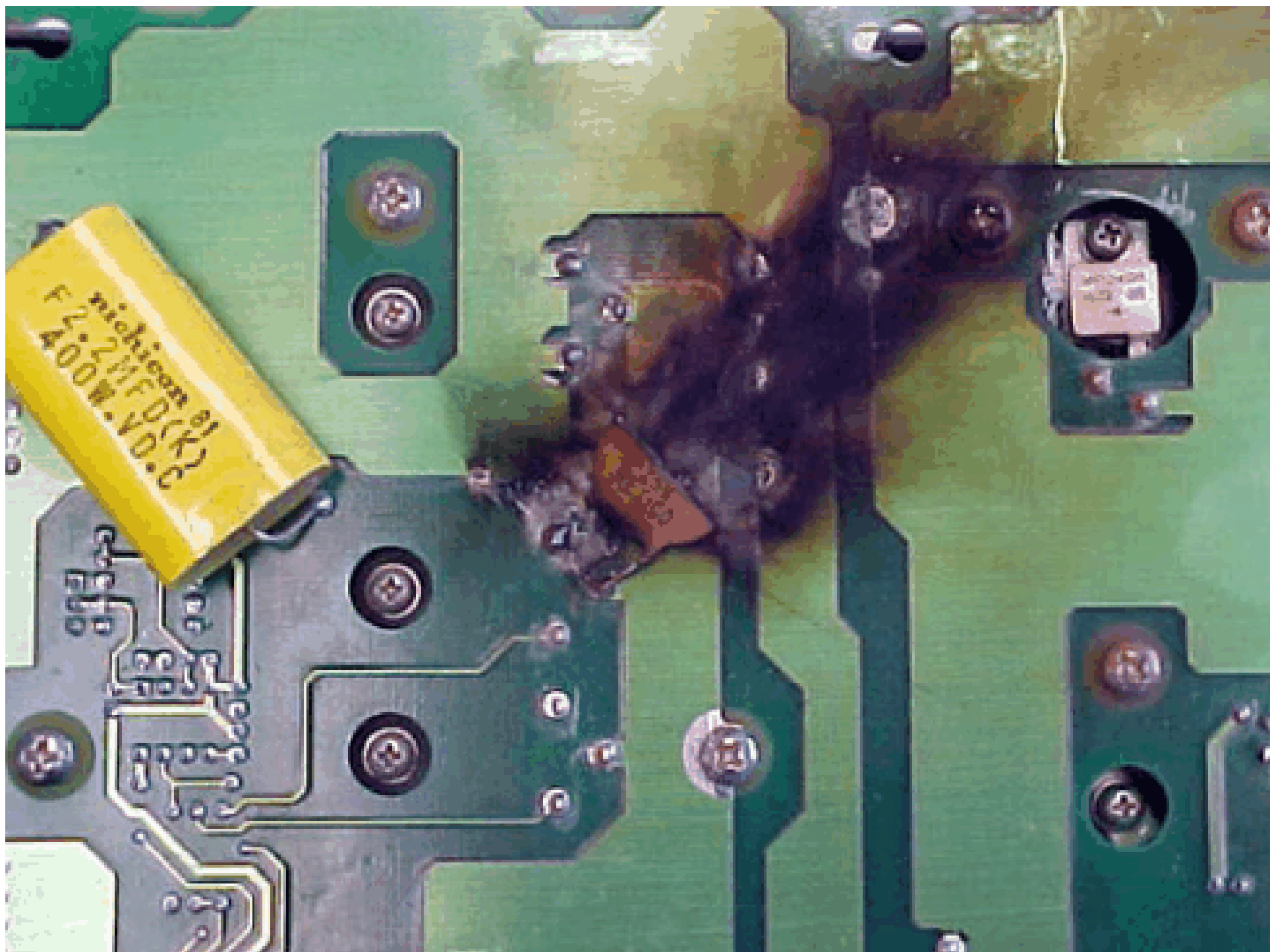
- The challenge - protect your radio equipment



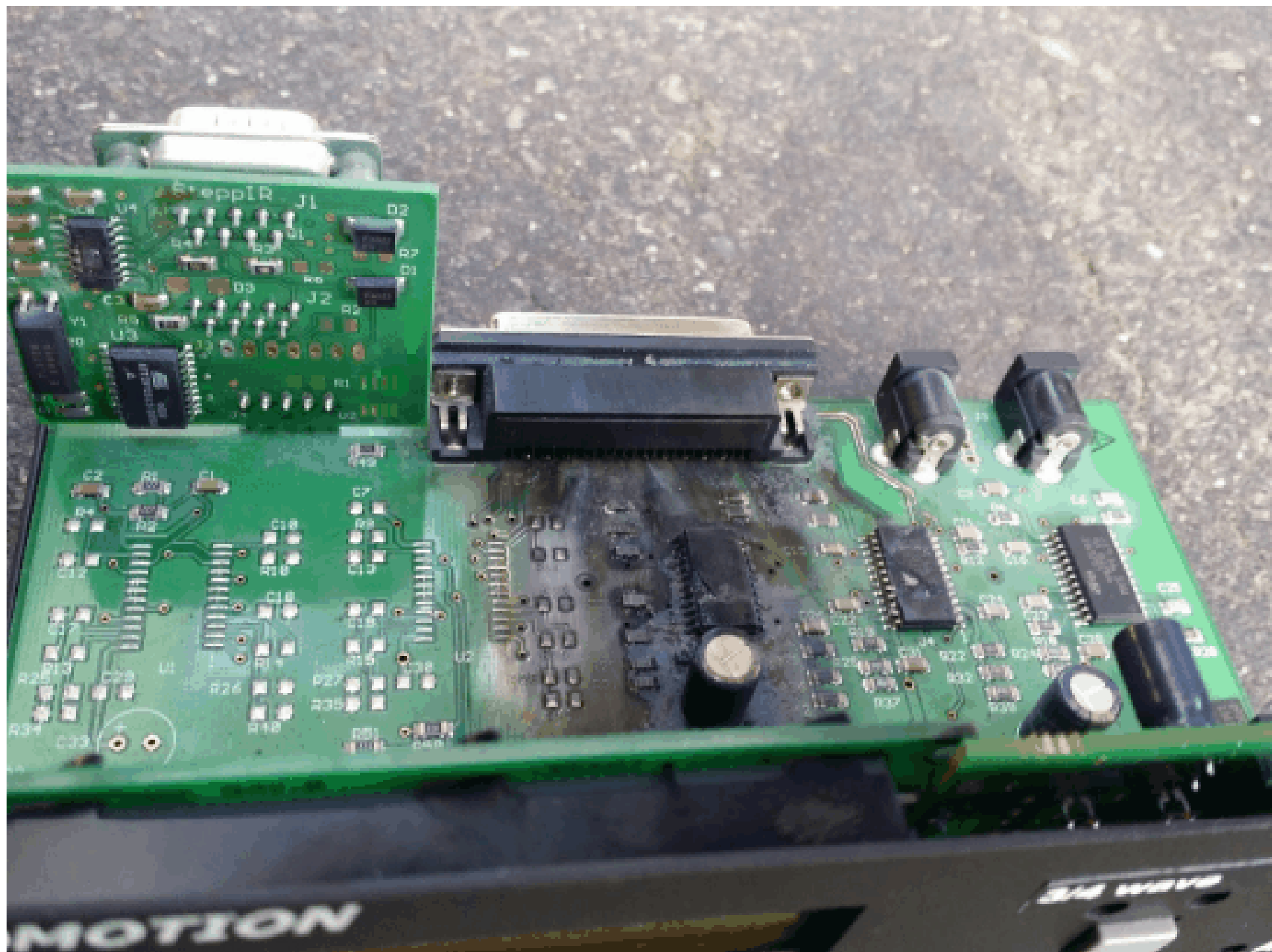
Disclaimer

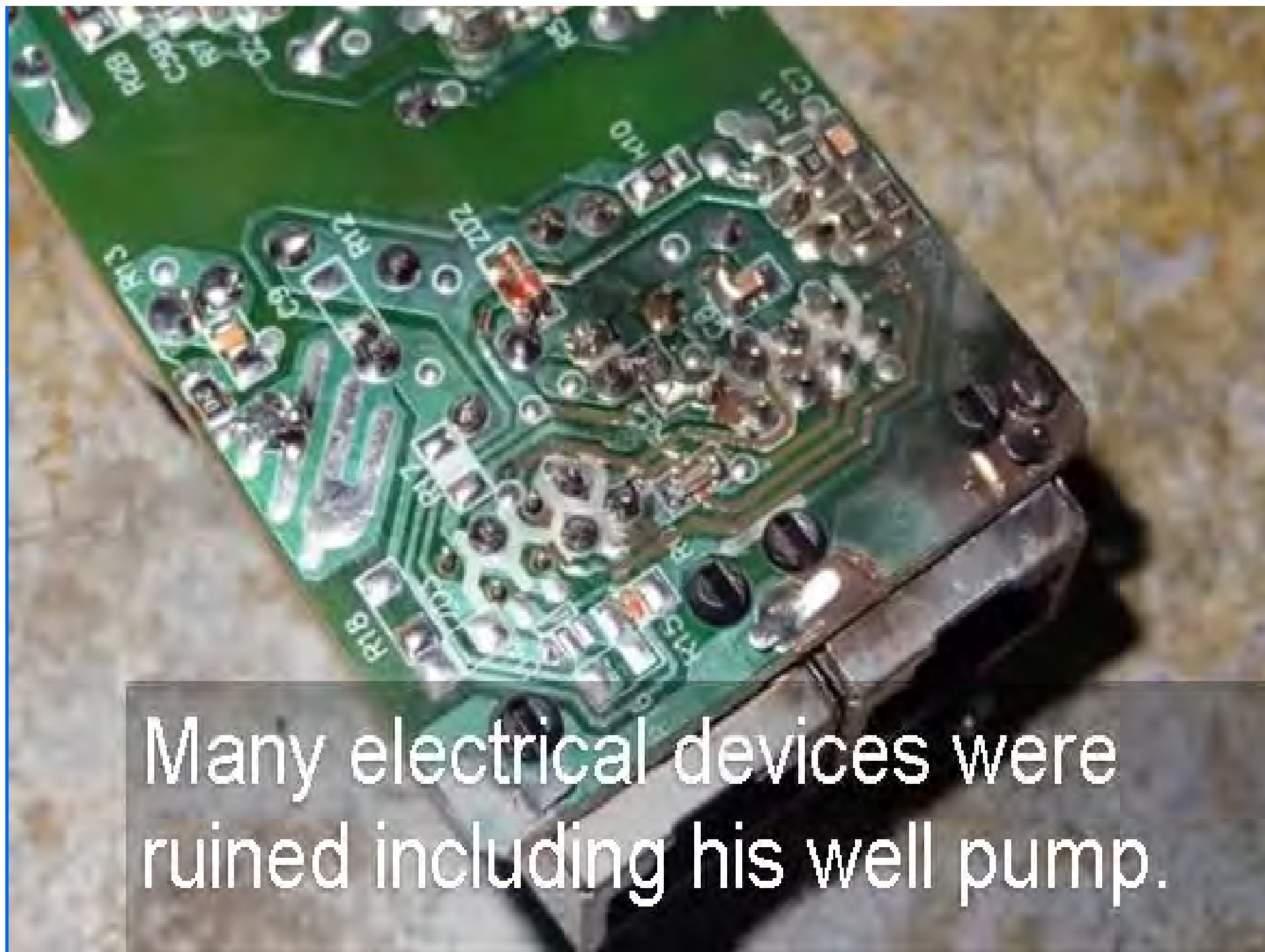
- 
- Have experience with lightning, lightning damage, lightning repair and lightning pervention
 - Cannot guarantee the accuracy or completeness of any information
 - Suggested lightning protection procedures may reduce total damage

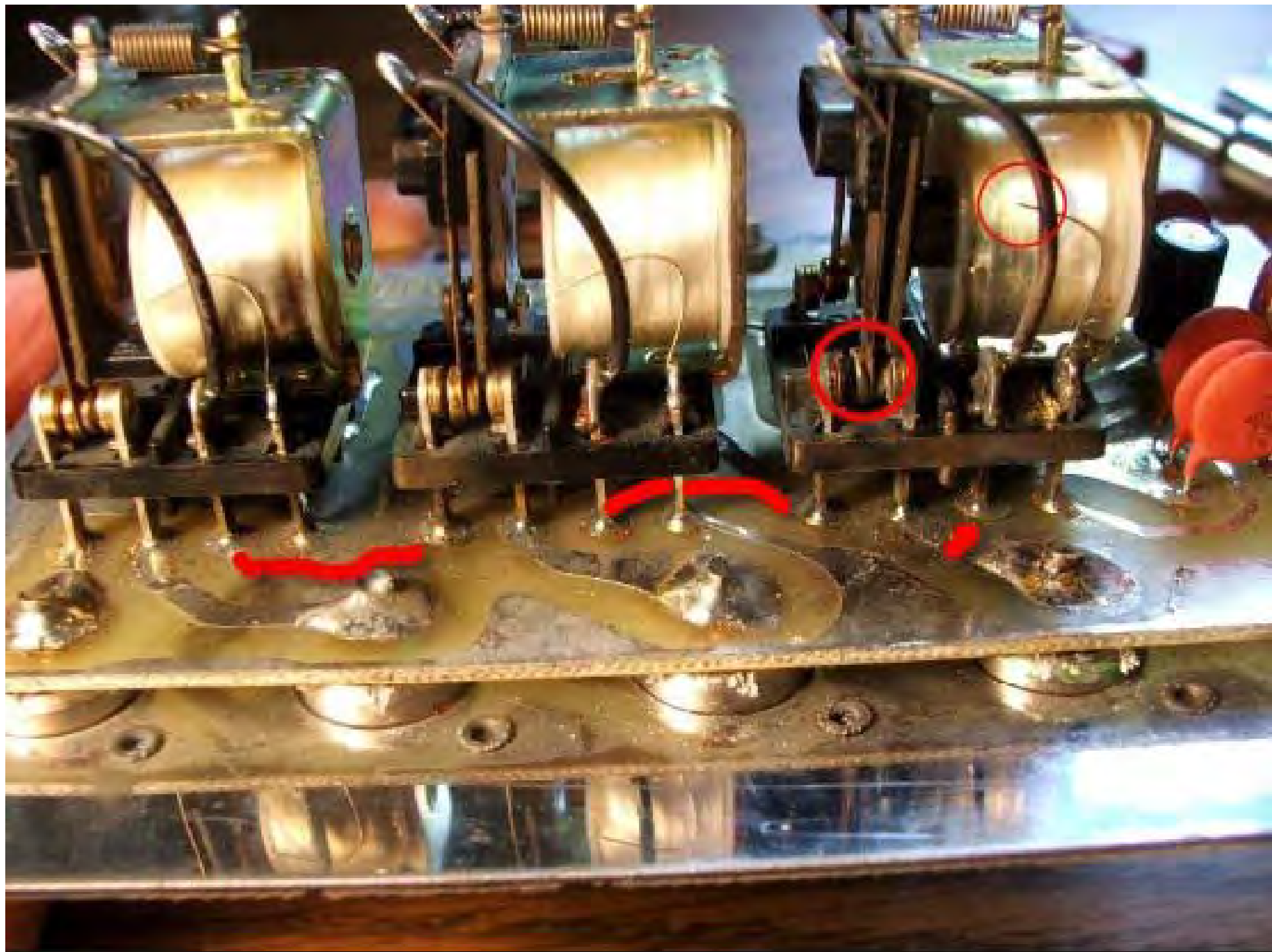








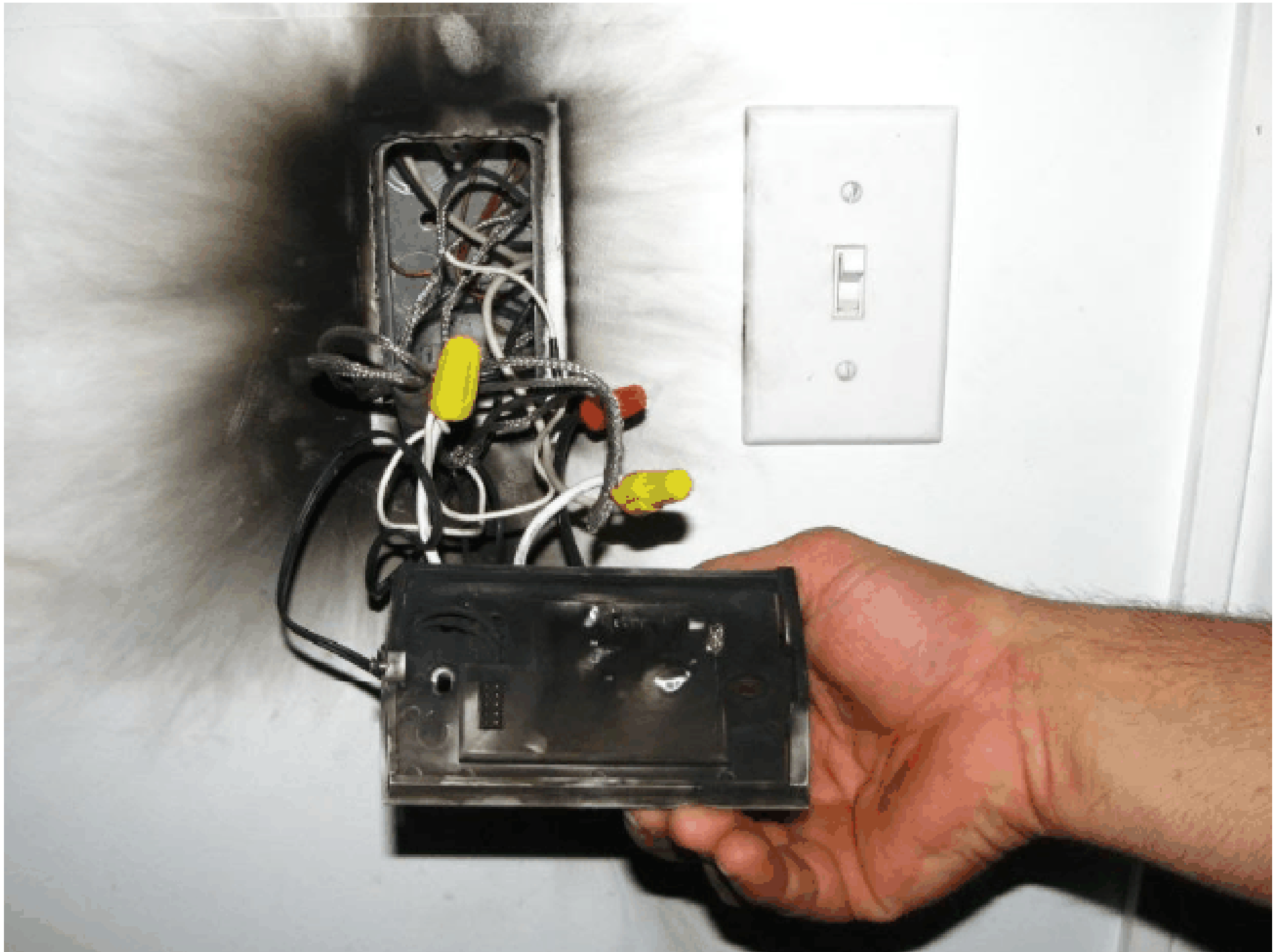








Hole in radio room cement floor.





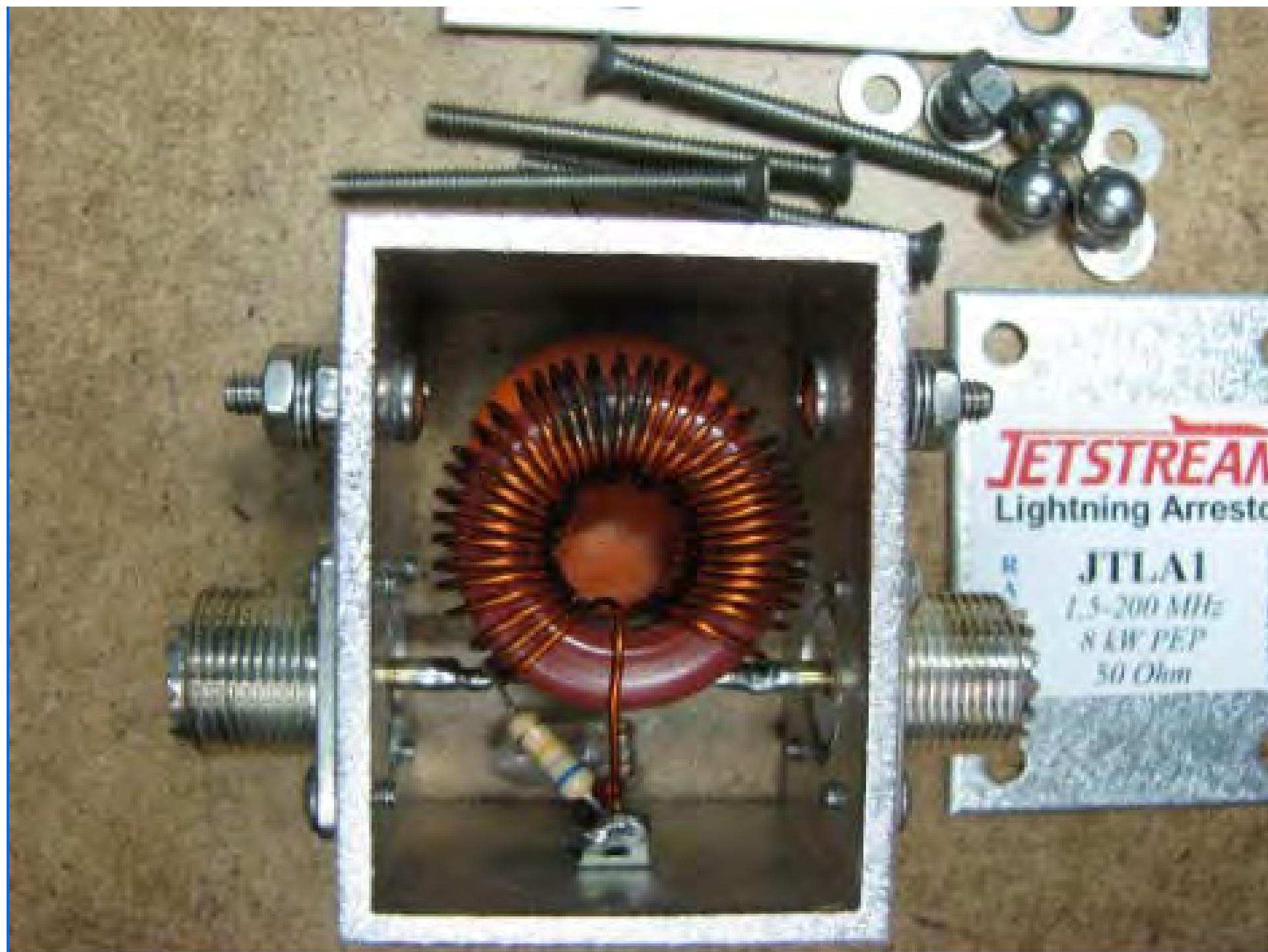












JETSTREAM
Lightning Arrestor

JTLA1

1.5-200 MHz

8 kW PEP

50 Ohm



Hook on pulley opened up.



This is what's left of his antenna wire known as ladder line.

The Challenge – protect your radio equipment

- What must be protected?
- Which protective components reduce damage?
- What methods reduce damage?
- 60 hertz grounding and radio frequency (RF) grounding
- ? Better grounding? copper wire or copper strap
- What is complete system grounding
- Myths
- Problems

References

1 of 2

- Alliance for Telecommunications Industry Solutions (ATIS)
- American National Standards Institute (ANSI)
- American Radio Relay League (ARRL)
- American Society of Mechanical Engineers (ASME)
- Australian Standards (AS)
- British Standards Institution (BS)
- Cooper, MA
- Federal Aviation Agency (FAA)
- Federal Communication Commission (FCC)
- http://en.blitzortung.org/live_lightning_maps.php?map=32
- Institute of Electrical and Electronics Engineers (IEEE)
- International Association of Electrical Inspectors (IAEI)
- International Electrotechnical Commission (IEC)
- Lightning, Uman, MA, 1982

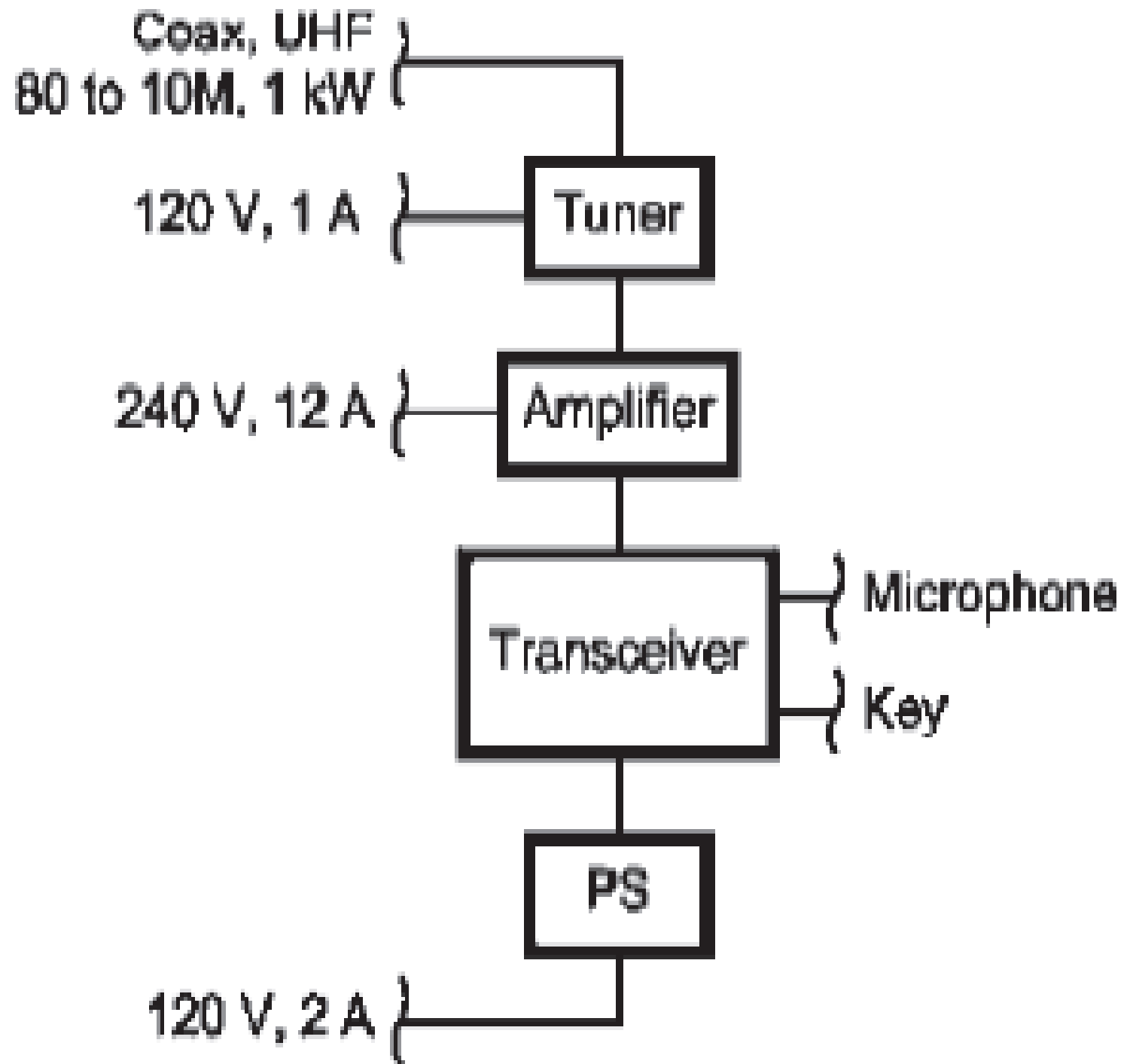
References

2 of 2

- Lightning Injury Research Program (LIRP)
- Motorola Corporation
- National Electrical Manufacturers Association (NEMA)
- National Fire Protection Association (NFPA)
- National Oceanic and Atmospheric Administration (NOAA)
- PolyPhaser Corporation
- Smith Power Corporation
- Telecommunications Industry Association (TIA)
- The “Grounds” for Lightning and EMP Protection, Block, RR, 1987
- Underwriters Laboratories (UL)
- United States Department of Defense (DoD)
- United States Federal Aviation Administration (FAA)
- United States National Weather Service (NWS)

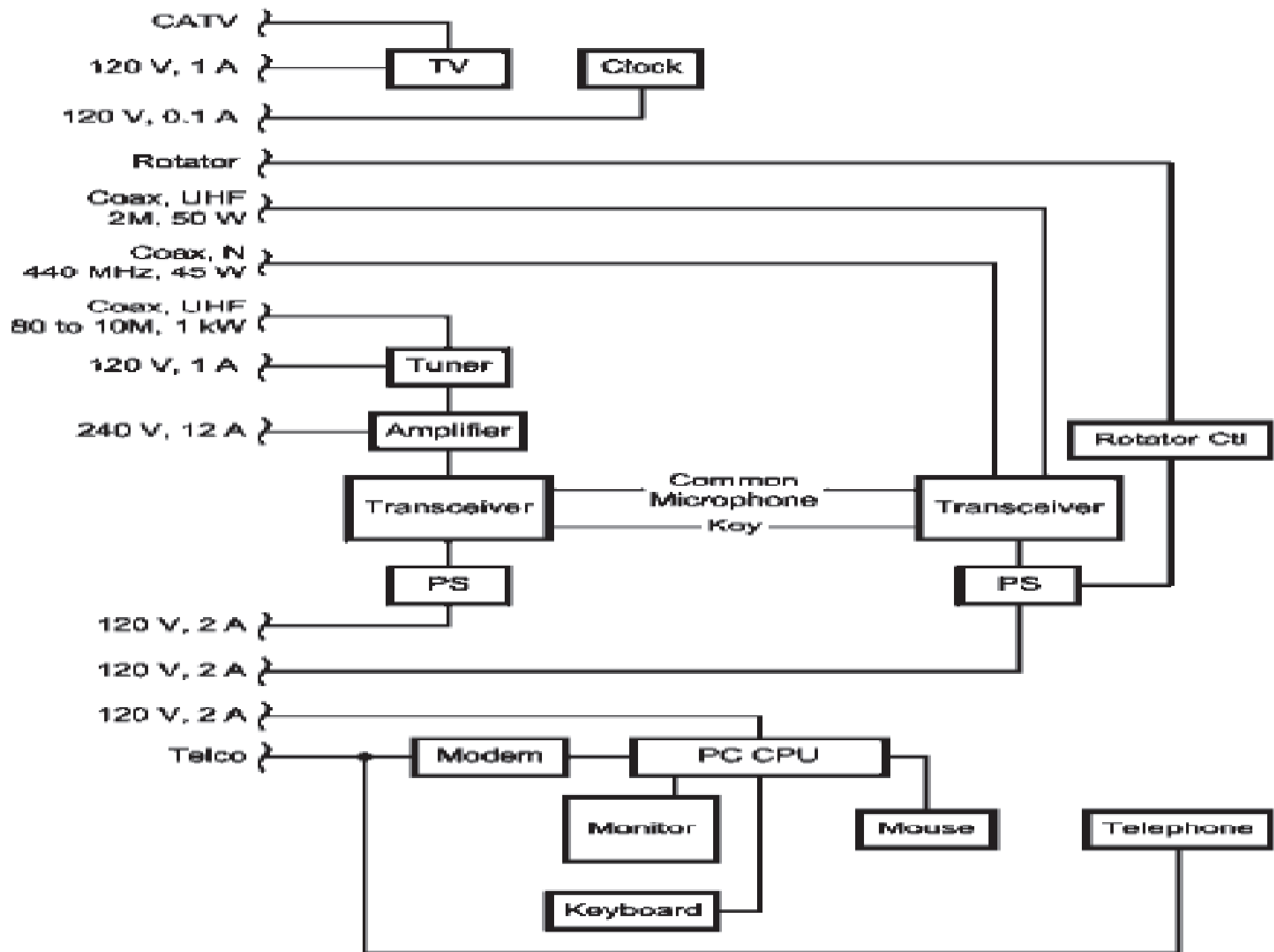


What must be protected?



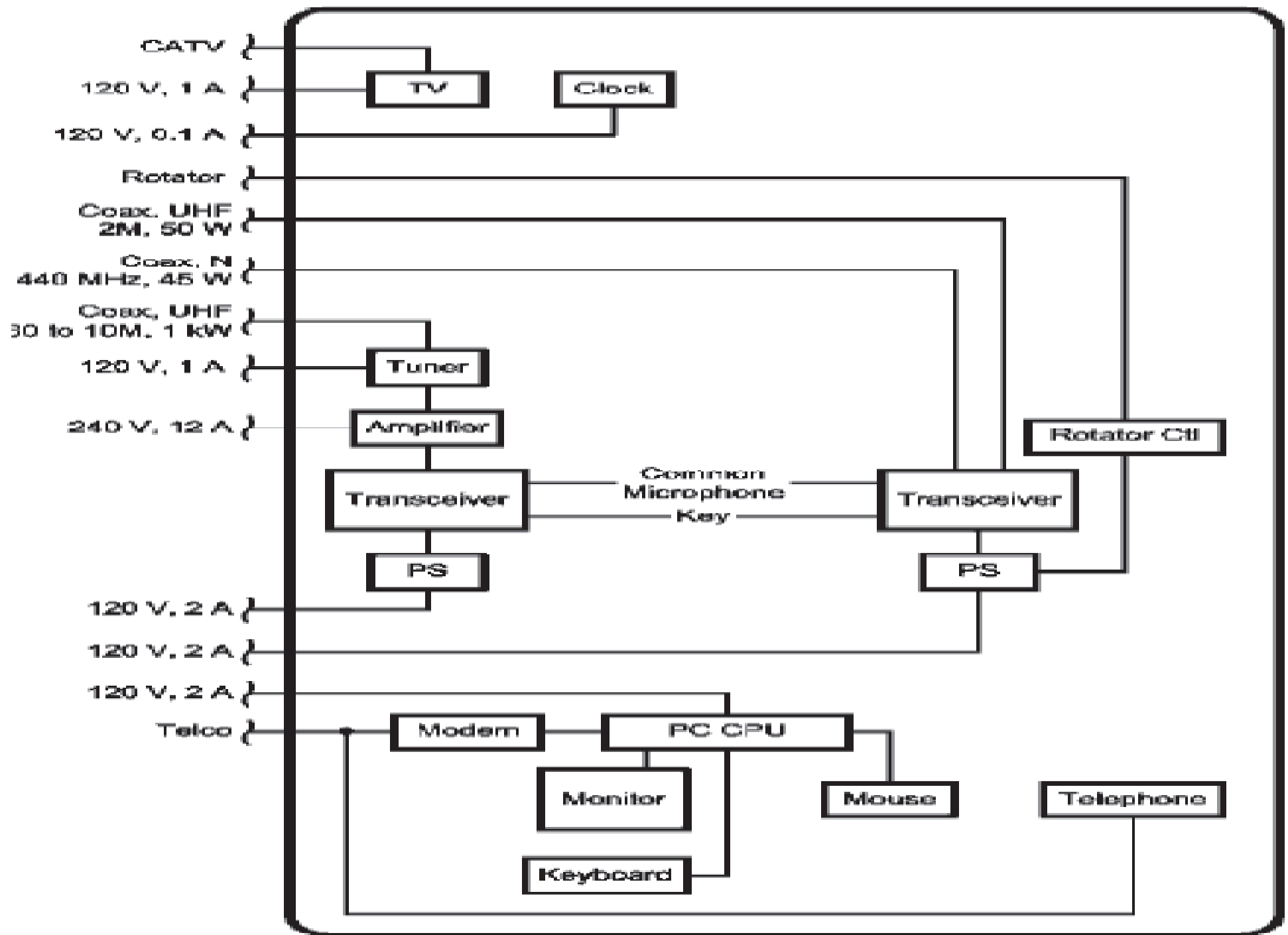


Closer Look





Protect all the equipment



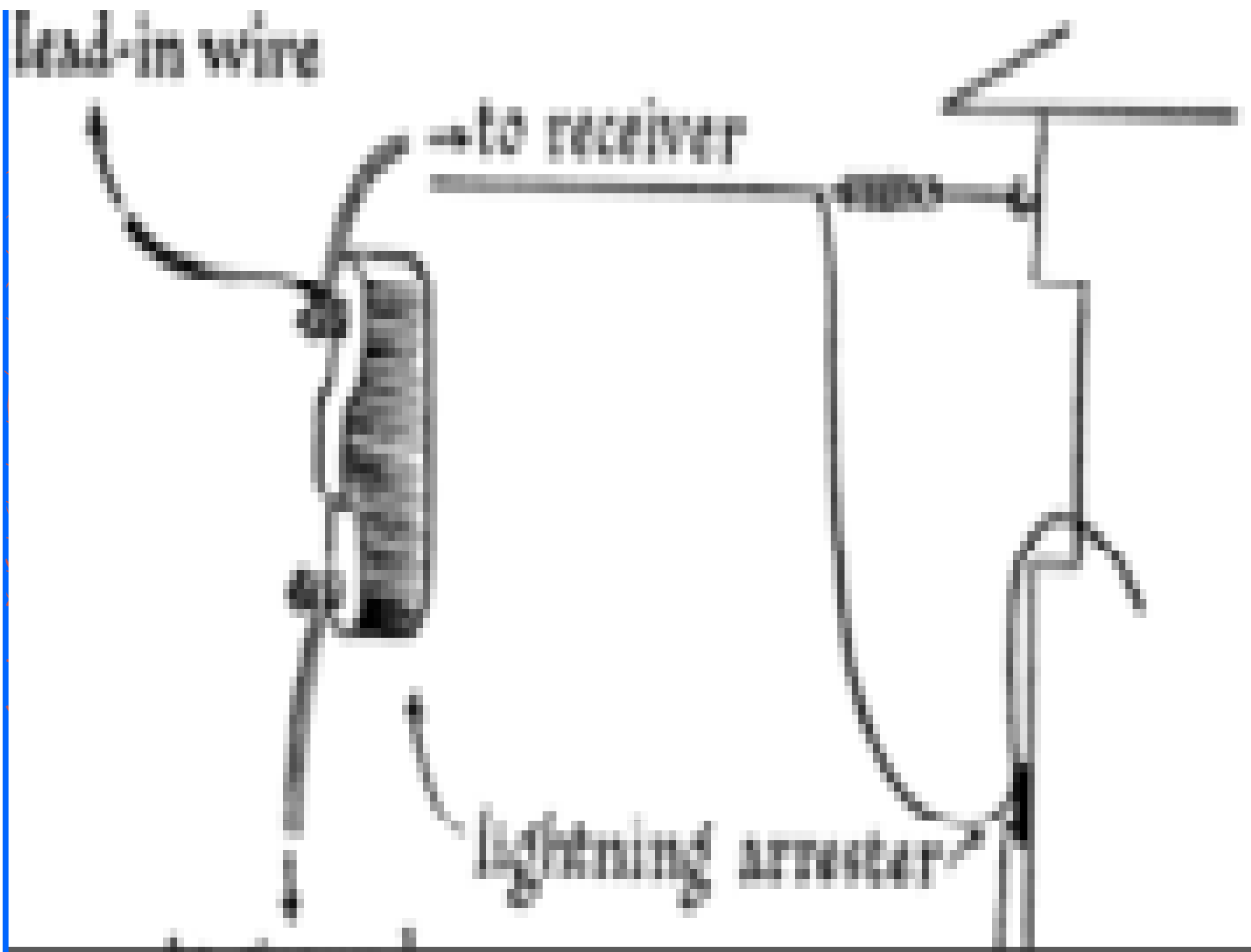


**Which protective components
reduce damage?**

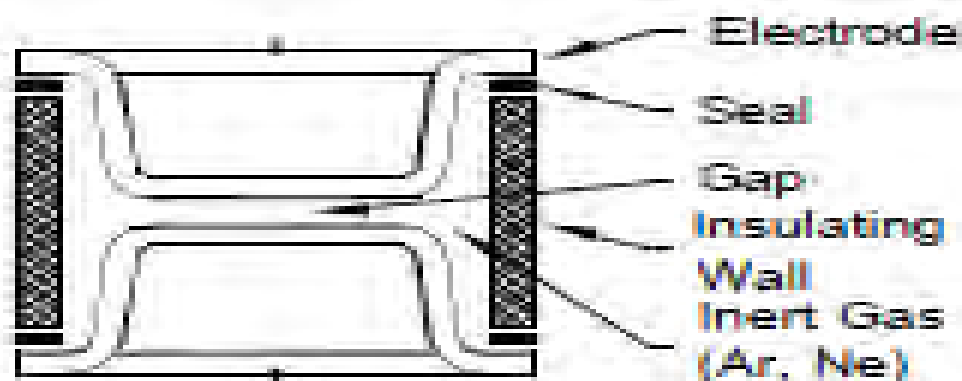
lead-in wire

to receiver

lightning arrester

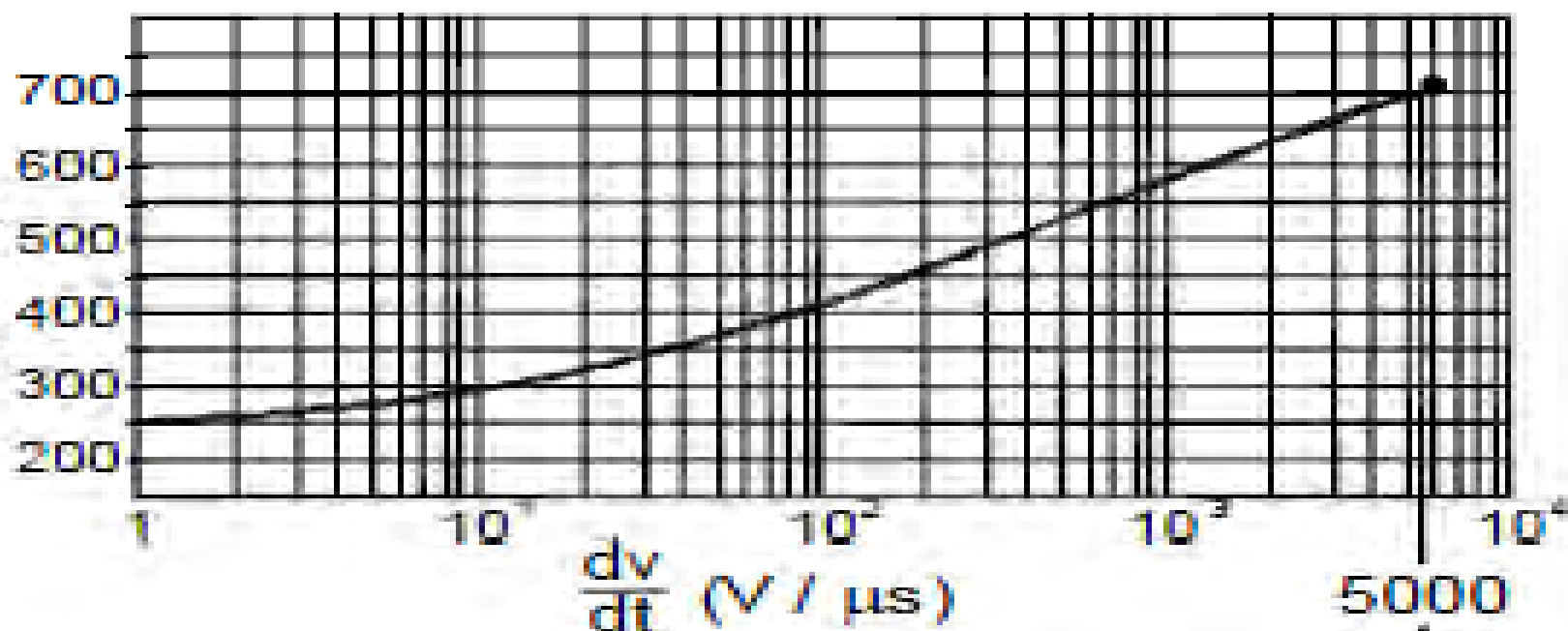


Cut-away
view of gas
tube surge
arrestor
(not to
scale)



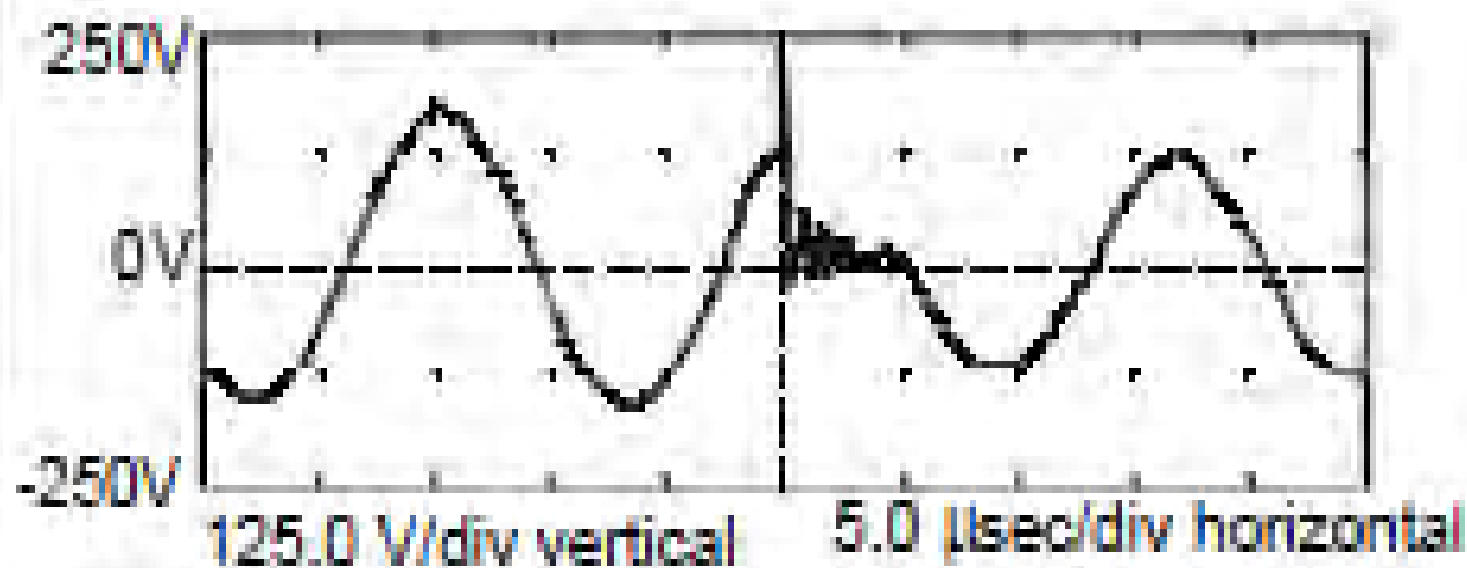
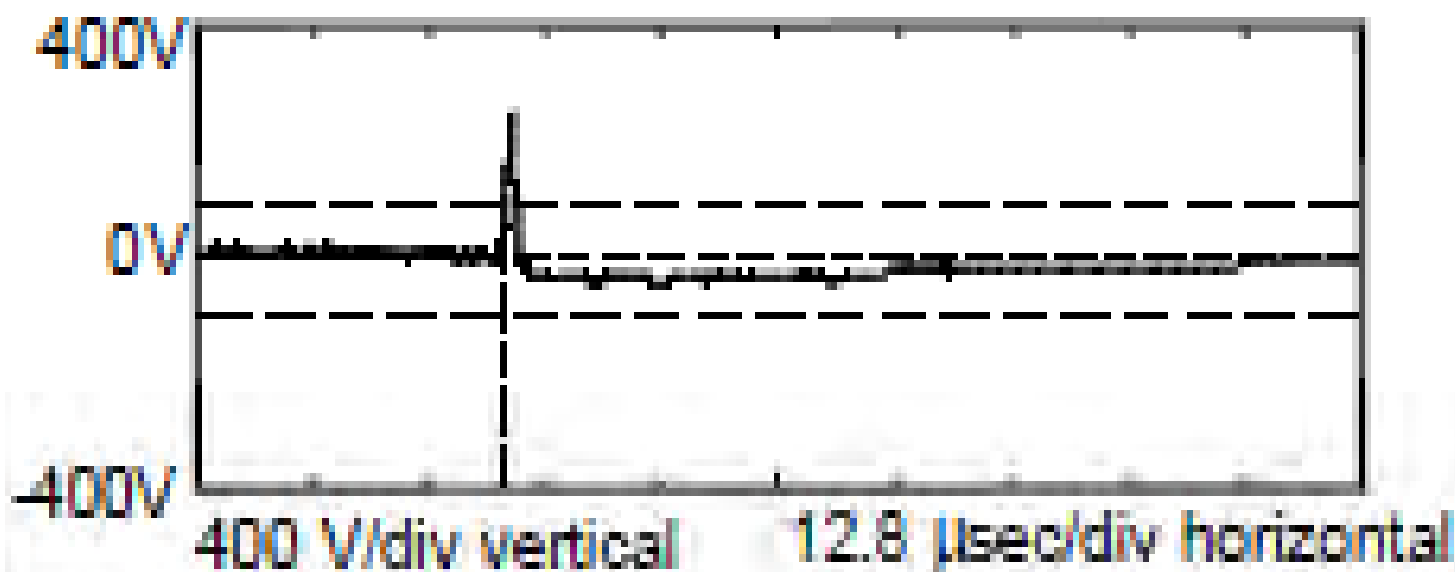
Gas Tube Arrestor
Symbol

Impulse
Firing
Voltage
(V)



ANSI C62.41, $\frac{dv}{dt} = 5000 \text{ V} / \mu\text{s}$
 $1.2 \times 50 \mu\text{s}$
 Firing Voltage $\approx 700 \text{ V}$

53.3 V peak
61° phase position
3.0 μsec rise time
1.7 mJoules (50 Ω)



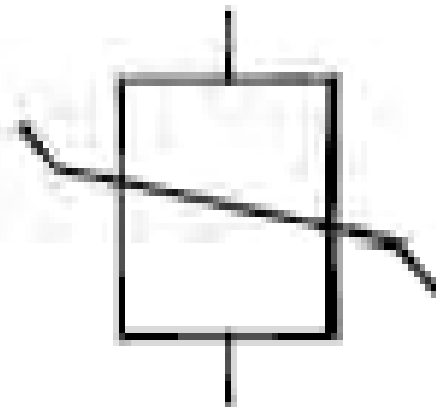
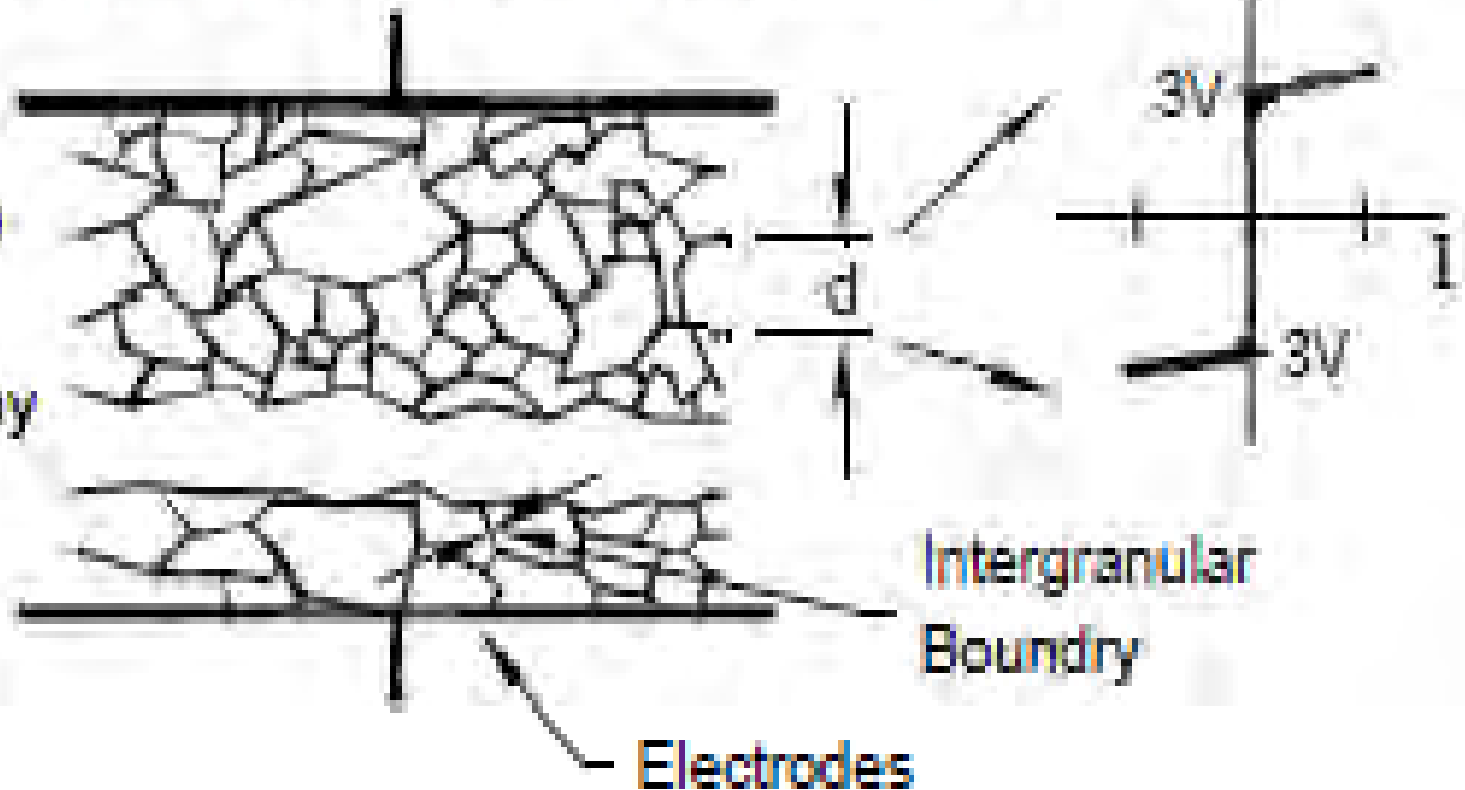
LINE-NEUTRAL IMPULSE

INTRATECH COMPUTER

Sept 24, 1987 6:26 AM

Schematic of MOV Microstructure

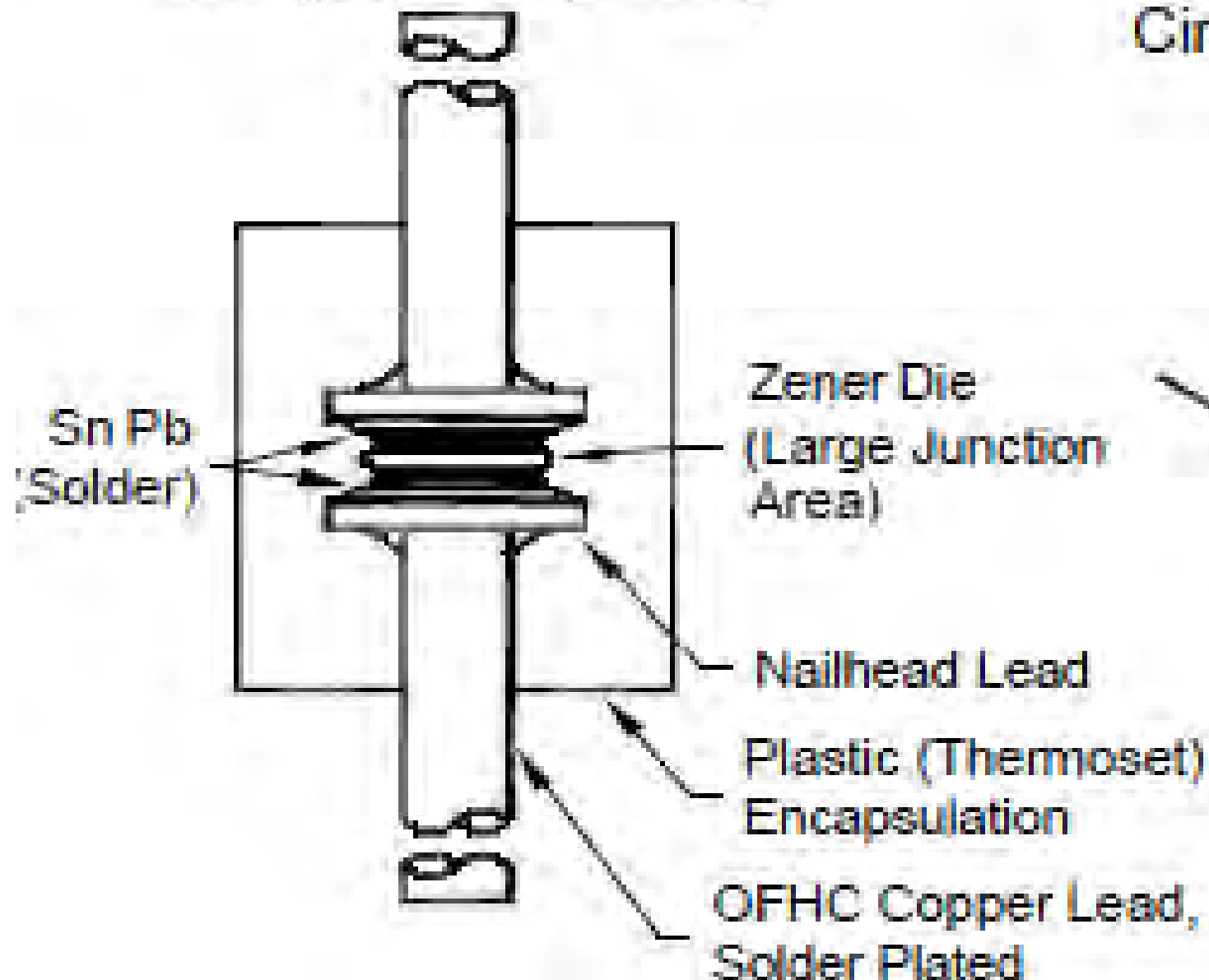
Grains of
conducting ZnO
(ave. size " d ")
are separated by
intergranular
boundaries



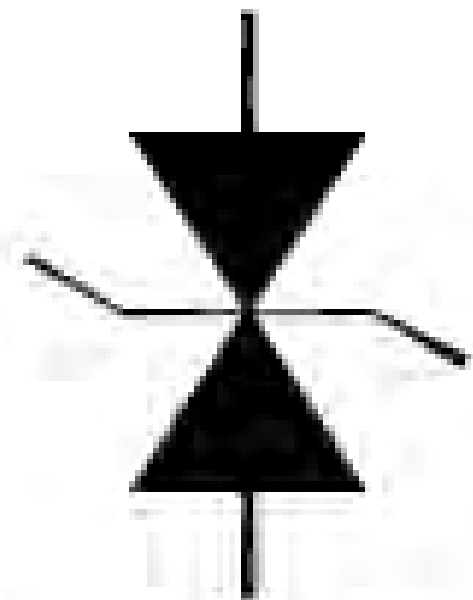
MOV
Circuit Symbol

Silicon Avalanche Diode (SAD)

SAD (Cut-Away View)



Bipolar SAD
Circuit Symbol





What methods reduce damage?



Protector types

Protector types - AC main power

- Four-layer semiconductor

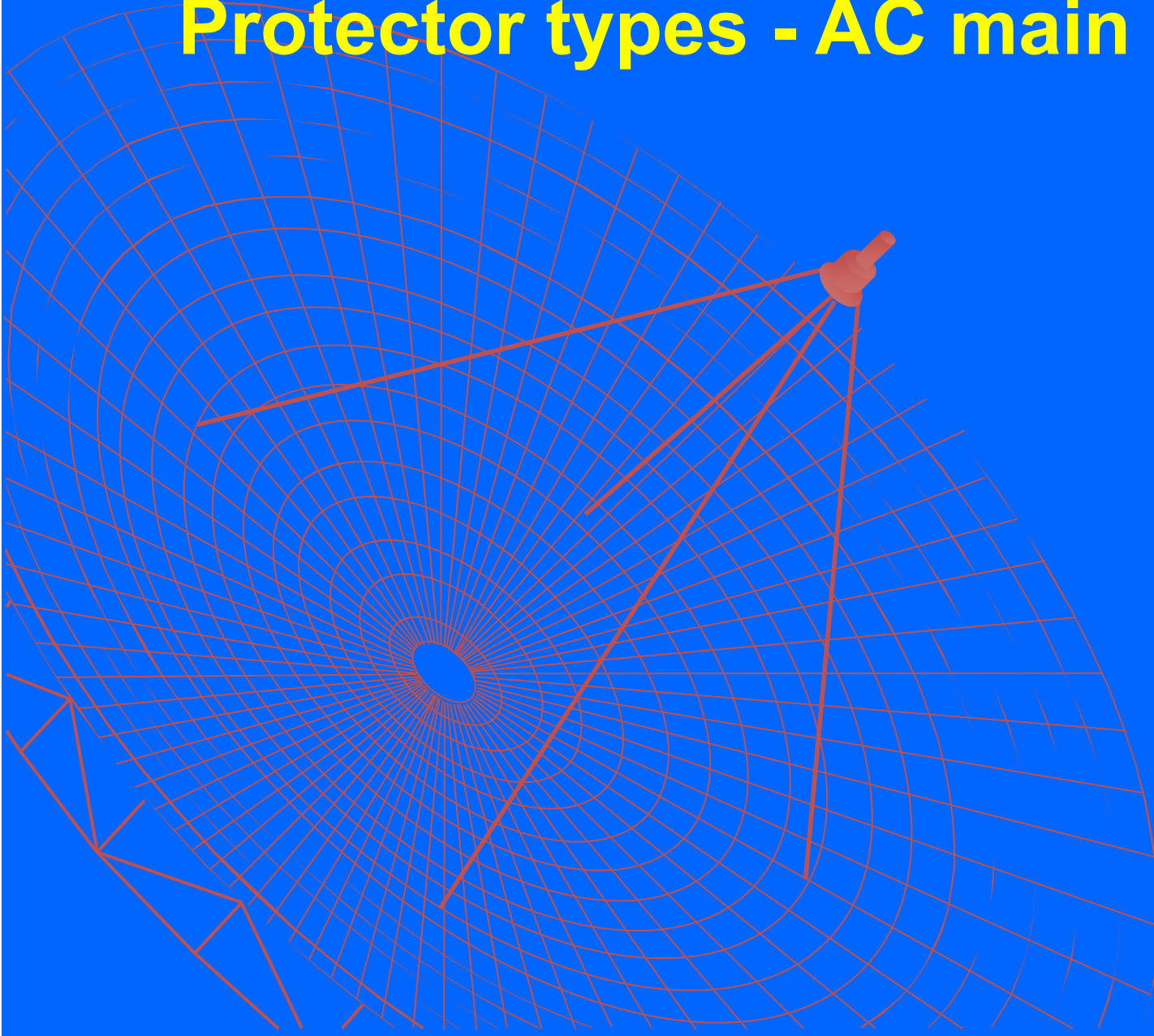
“Follower” or negative resistance

Used on telephone or control lines

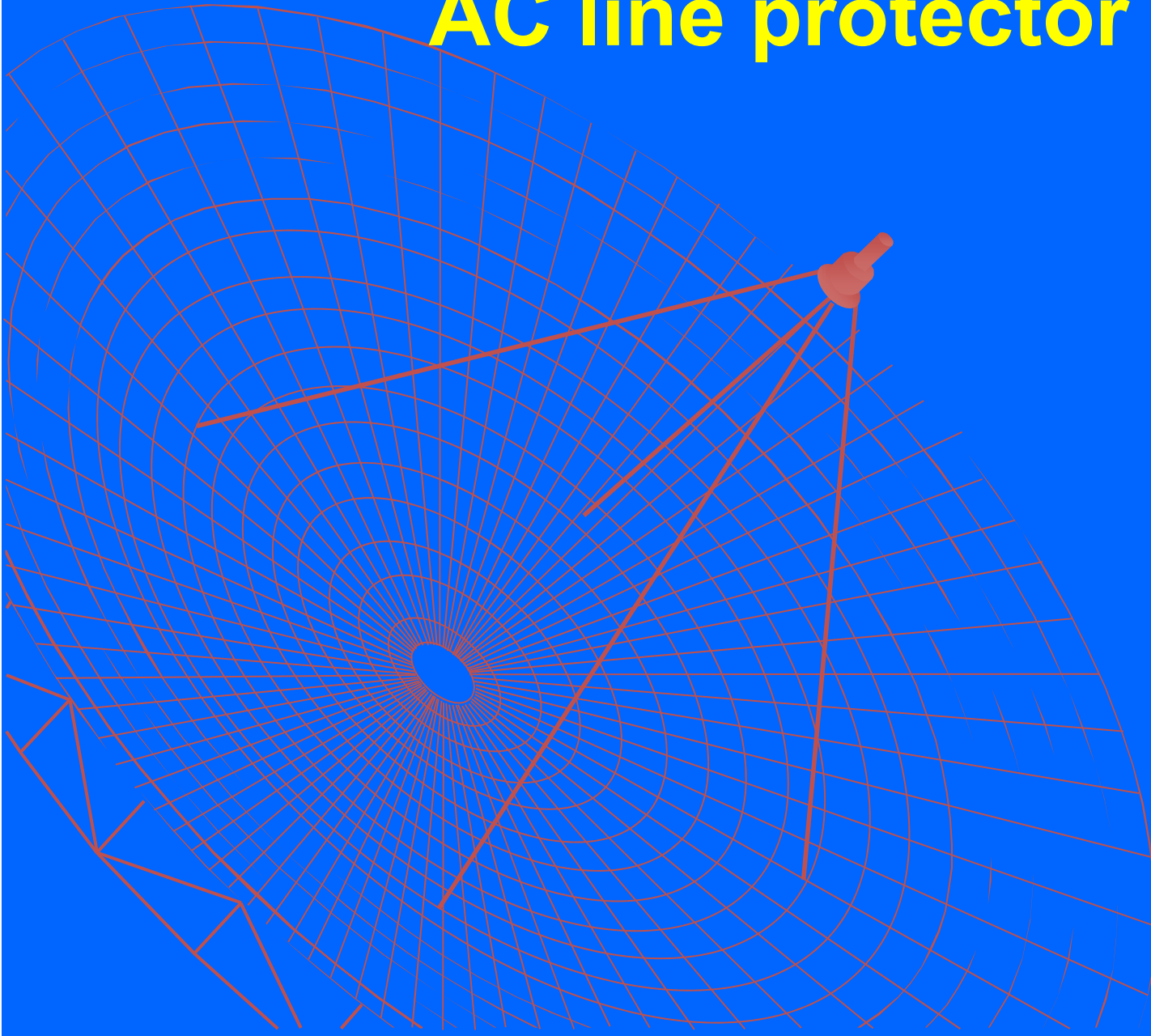
- Silicon Controlled Rectifier

Very fast when used with SAD or MOV

Protector types - AC main power



AC line protector



Battery and charger protection

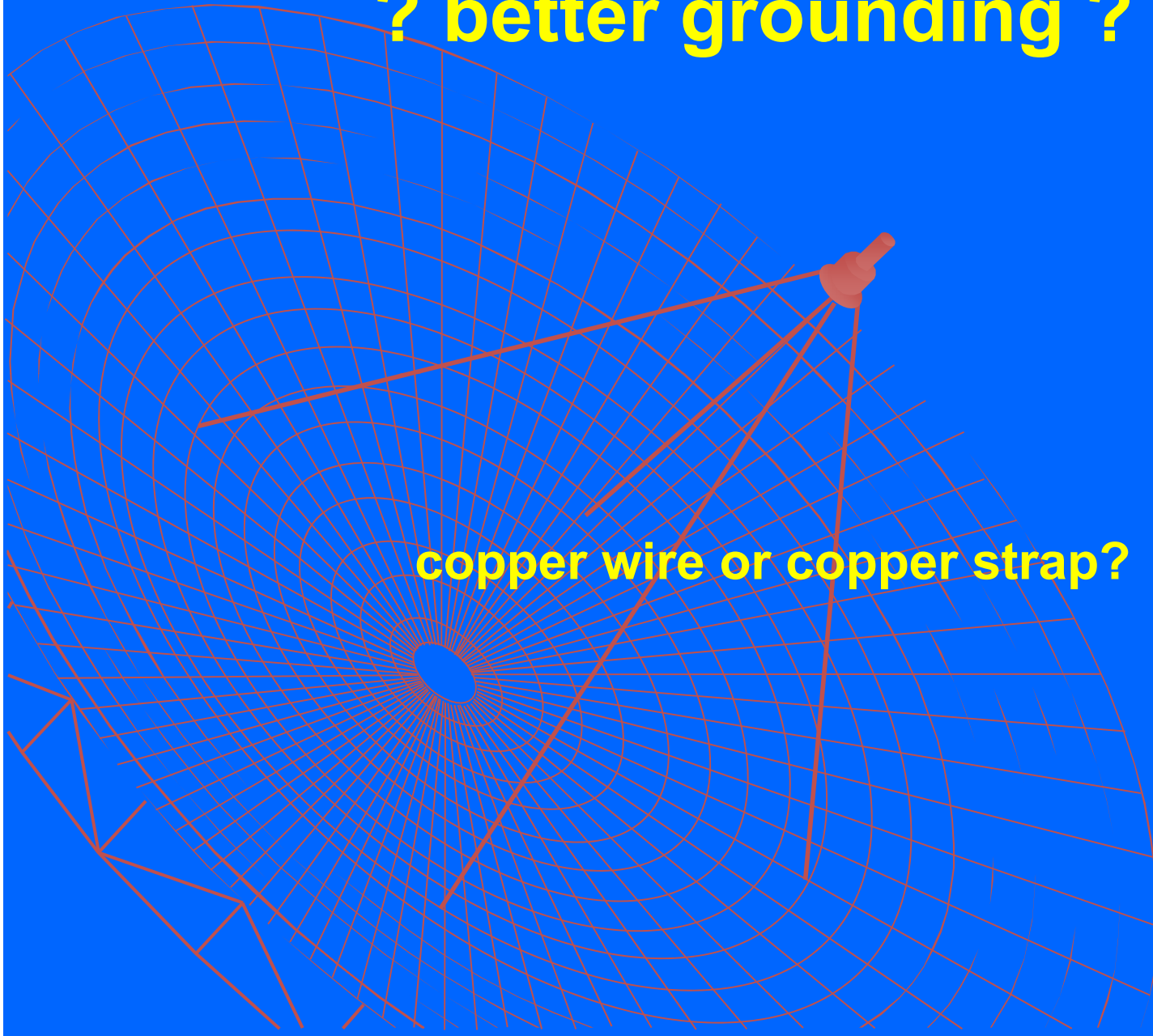




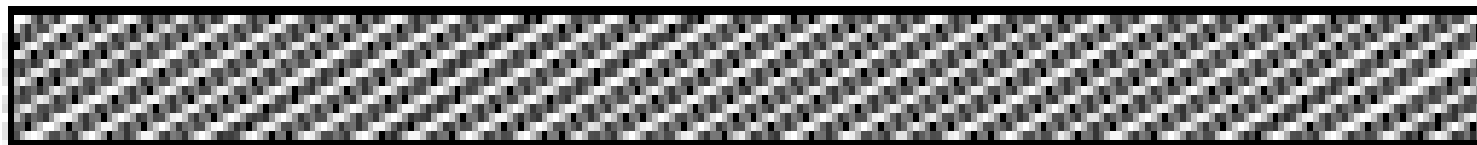


? better grounding ?

copper wire or copper strap?



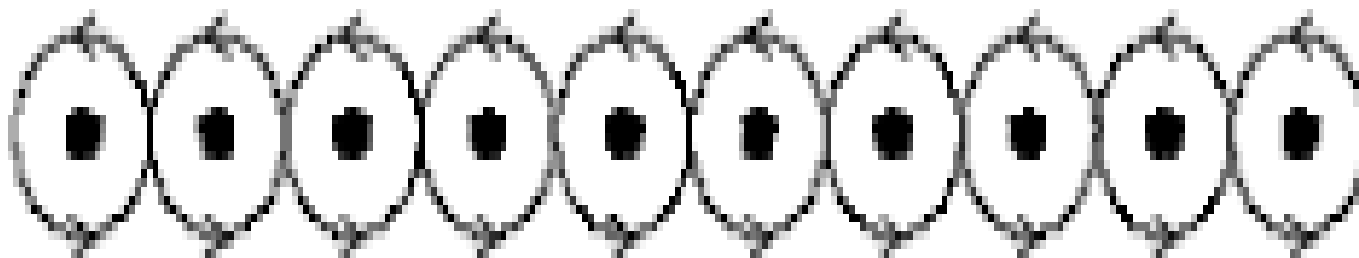
A



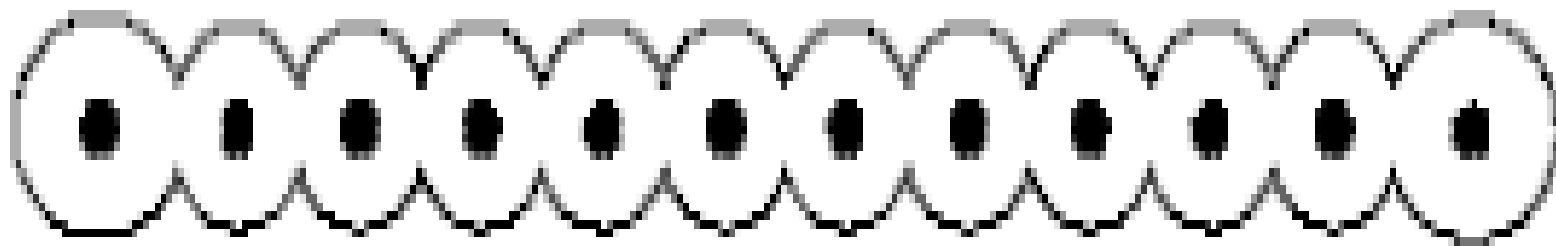
B



C



D



┌

Grounding conductors

Inductance equations for copper conductors

- Round copper wire $L = 2\ell \{ \ln(4\ell/d) - 1 \} \times 10^{-7} \mu\text{H}$
- Rectangular copper strapping $L = 2\ell \{ \ln[2\ell/(b + c)] + \frac{1}{2} \} \times 10^{-7} \mu\text{H}$
- Round copper tubing $L = 2\ell \{ \ln(2\ell/r) - \frac{3}{4} \} \times 10^{-7} \mu\text{H}$

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 $\mu\text{H}/\text{m}$	0.0104 inch^2
• # 6 copper wire:	1.18 $\mu\text{H}/\text{m}$	0.021 inch^2
• 1/2" copper water pipe:	0.91 $\mu\text{H}/\text{m}$	0.307 inch^2
• 2" x 0.011" copper strap:	0.84 $\mu\text{H}/\text{m}$	0.022 inch^2
• 3/4" inch copper water pipe:	0.70 $\mu\text{H}/\text{m}$	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	13.00 mm
• 1/2 " copper water pipe:	1.96 inches	49.80 mm
• 2 " x 0.011 inch copper strap:	4.00 inches	101.60 mm
• 3/4 " copper water pipe:	2.36 inches	59.90 mm

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 μ s.
- #6 Copper wire: $\Delta V = 754$ volts
- 2" Copper strap: $\Delta V = 528$ volts
- Ohm's Law for Resistance
- $\Delta V = IR = 2.6$ volts, much smaller than the induced voltage...essentially negligible



Single point grounding

What must be bonded?



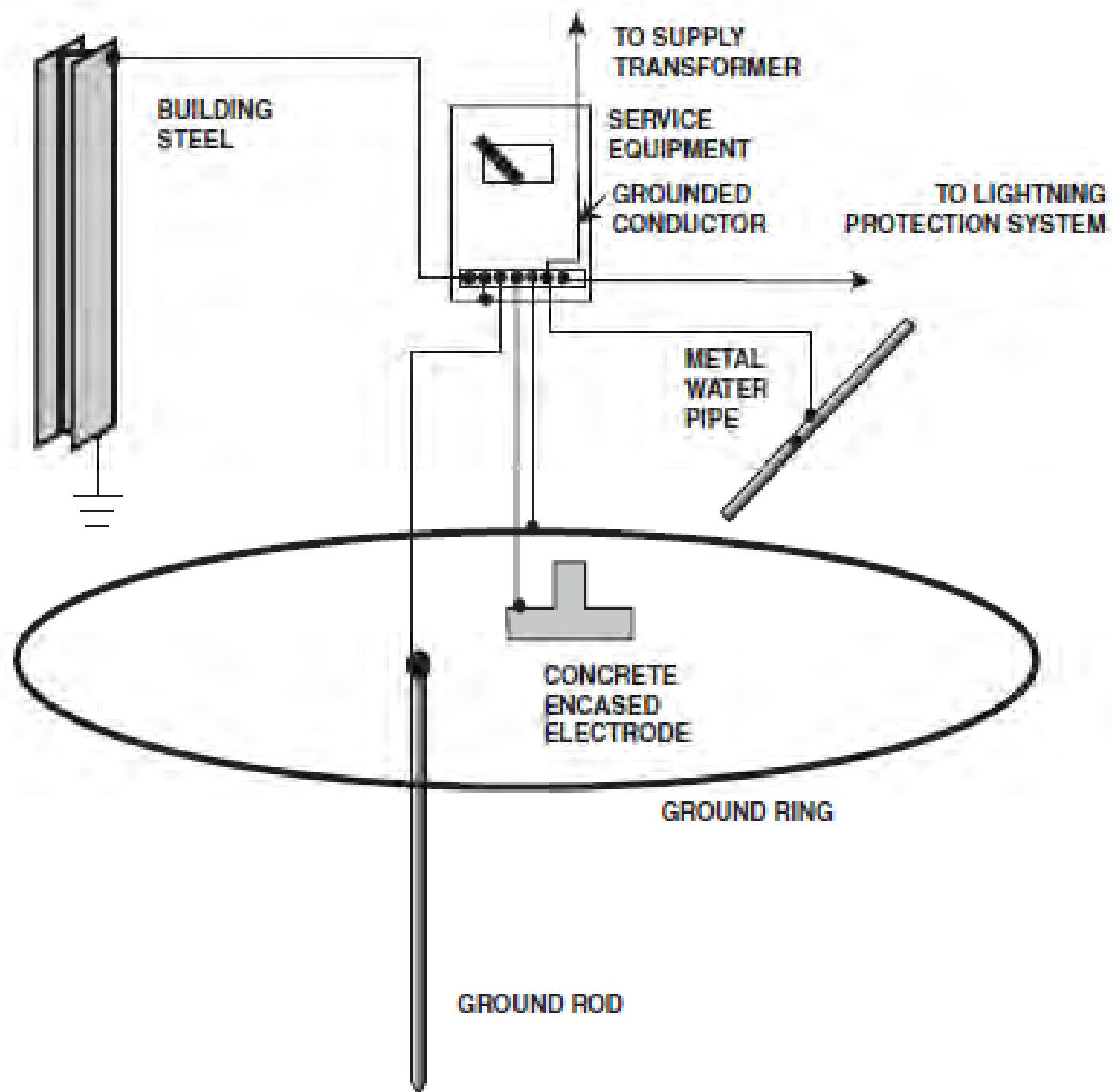
Everything must be bonded together

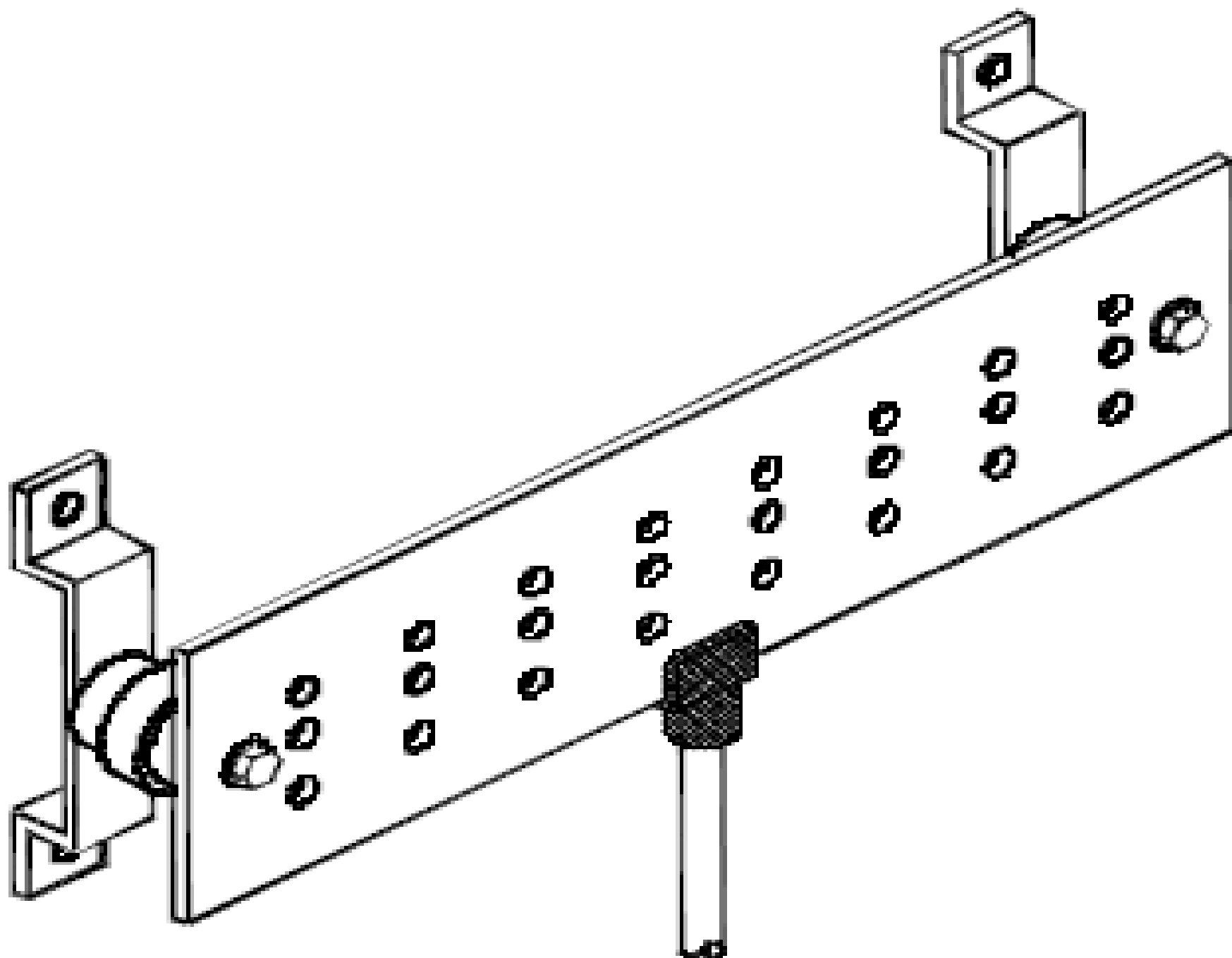
Separate grounds are unsafe and illegal!

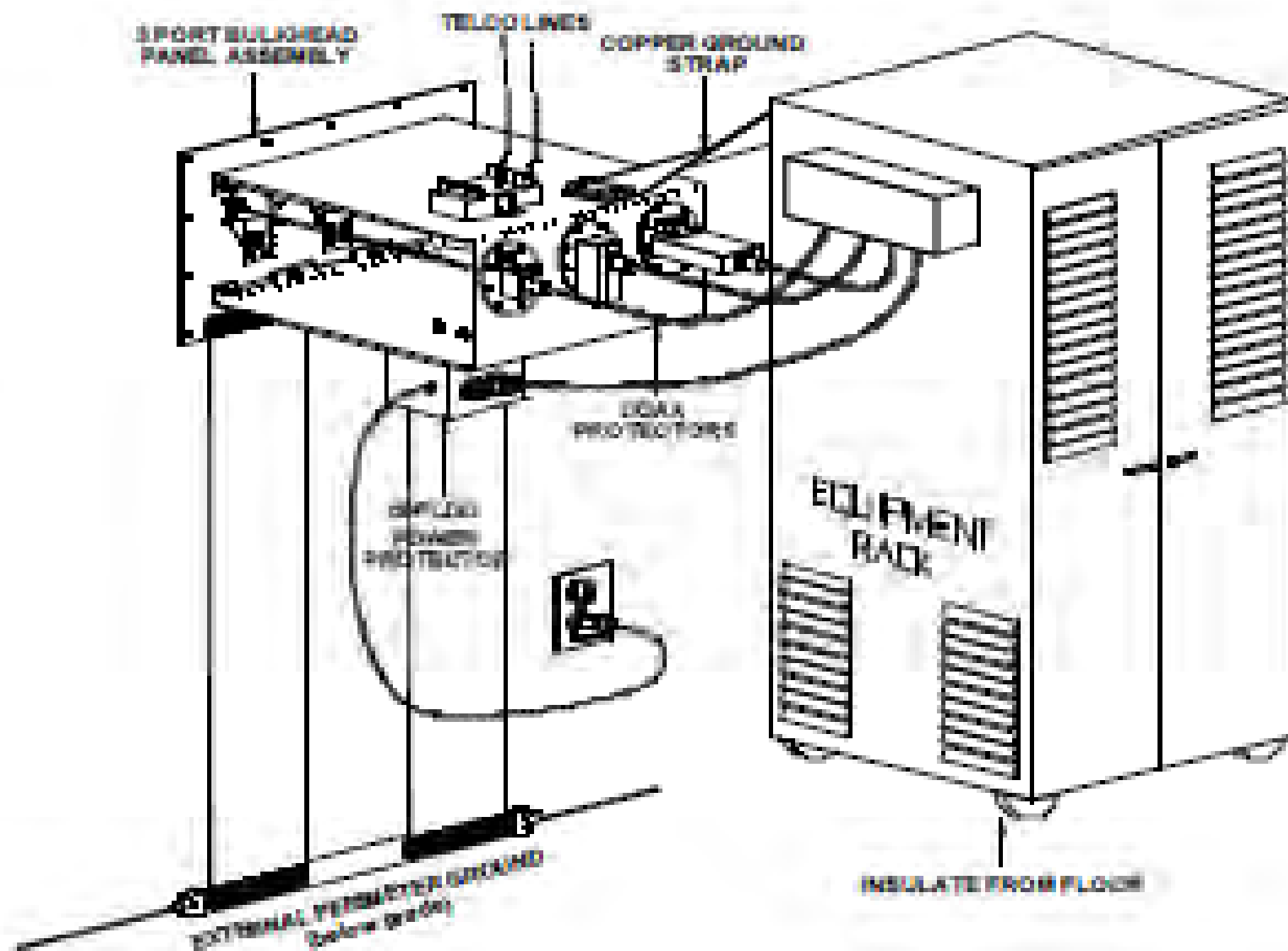


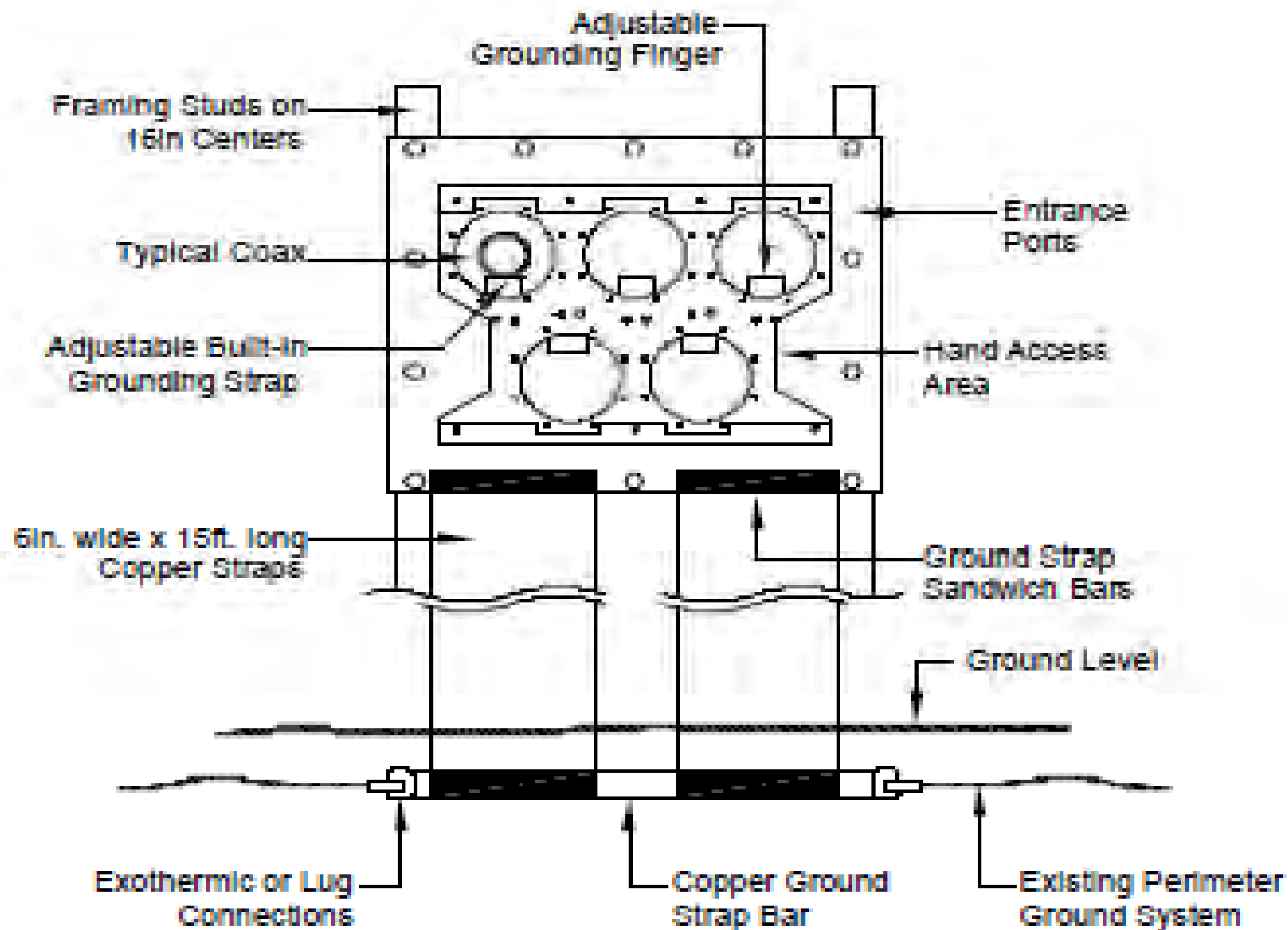
Why an earth connection?











(9) 7/8 coax = 24.75" circumference

(3) 1/2 coax = 4.75" circumference

Total Circumference = 29.50"

Typical Entry Panel

(1) #6x8' long ground wire

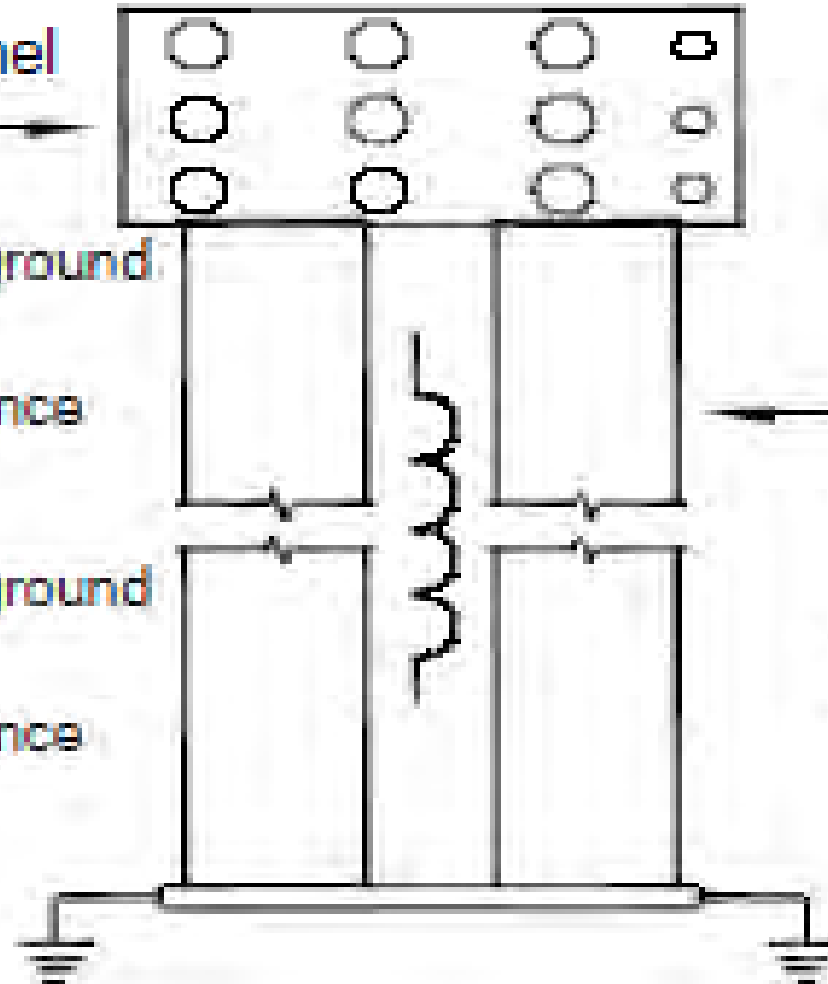
= 3.4 μ H inductance

= 8.2kV drop*

(1) #2x8' long ground wire

= 3.1 μ H inductance

= 7.8kV drop*



2" Copper Strap

= 24" circumference
(surface area)

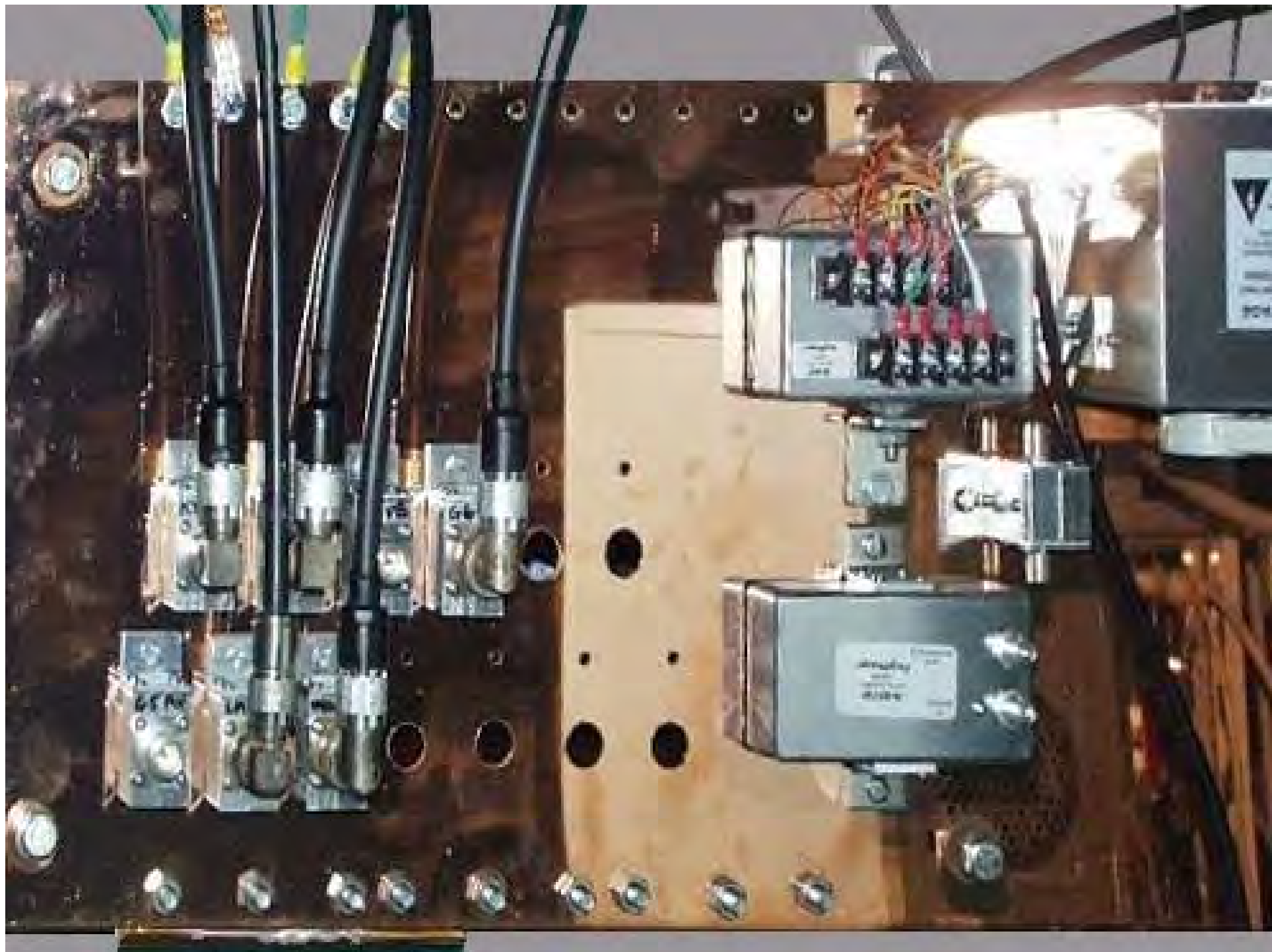
= 0.9 μ H inductance

= 2.5kV drop

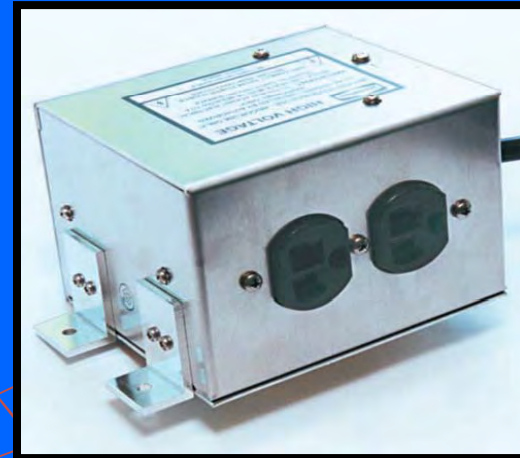
* 20kA/8 μ s pulse

Whole house surge protector





Lightning suppressors



Ron Block KB2UYT in QST

Coaxial In-Line Arrestor



IS-B50LU-C0 | Broadband dc Blocked Protector

The IS-B50 is a dc blocked 50 Ohm bulkhead mounted protector and should be connected directly to a bulkhead or a master ground bar

Availability: In stock

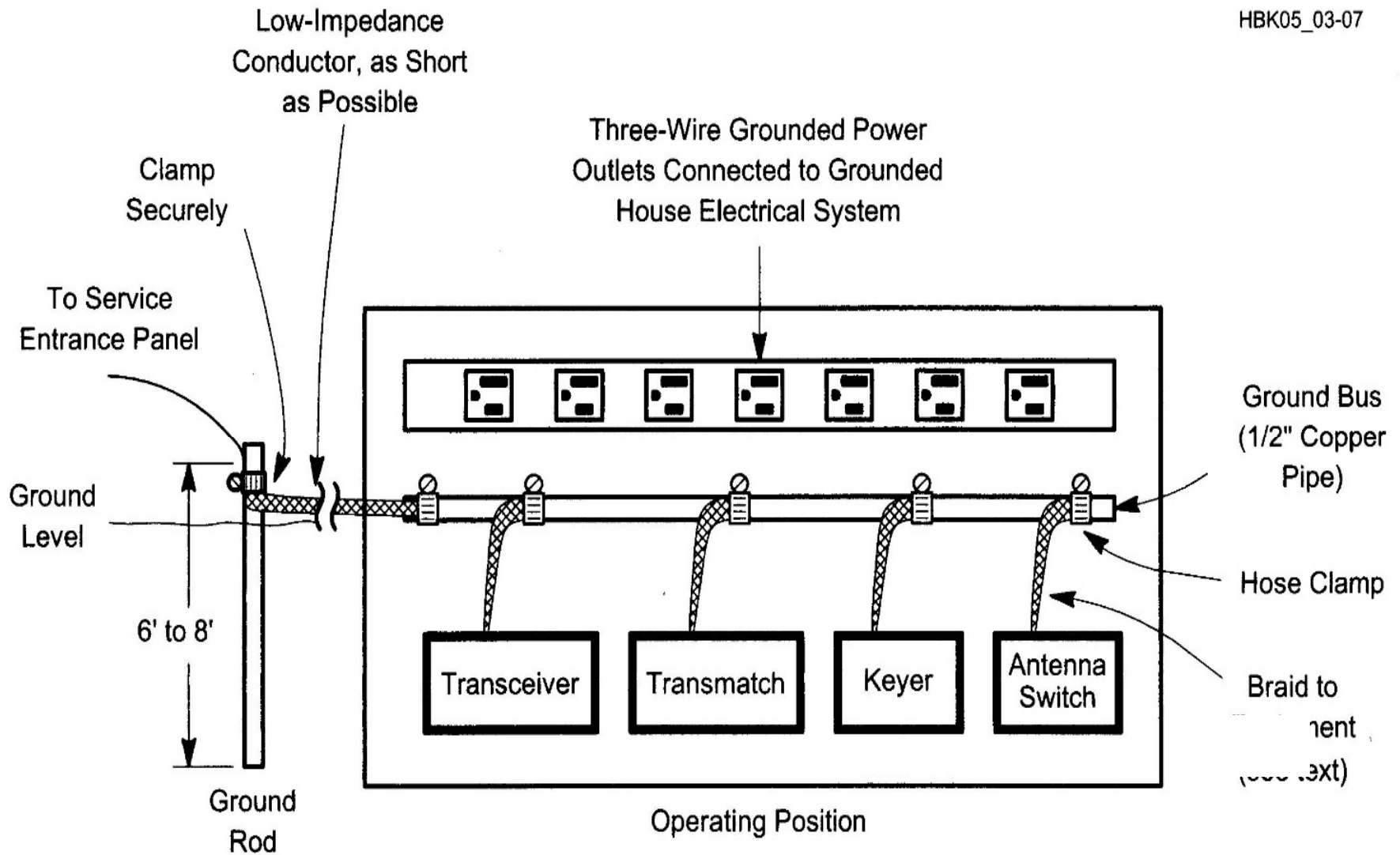
[Request Quote](#)

TECHNICAL SPECIFICATIONS

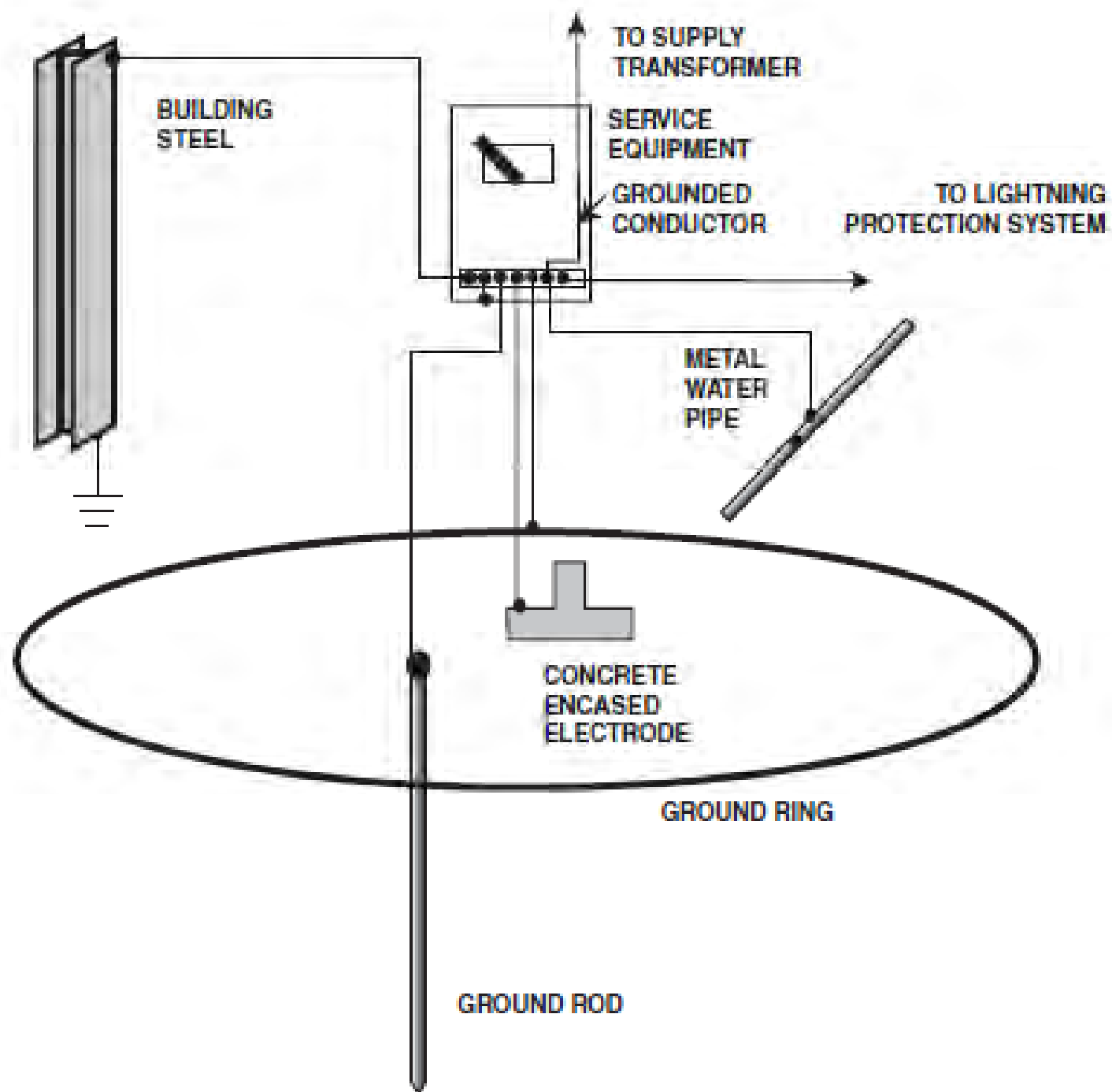
[Customer Print](#)

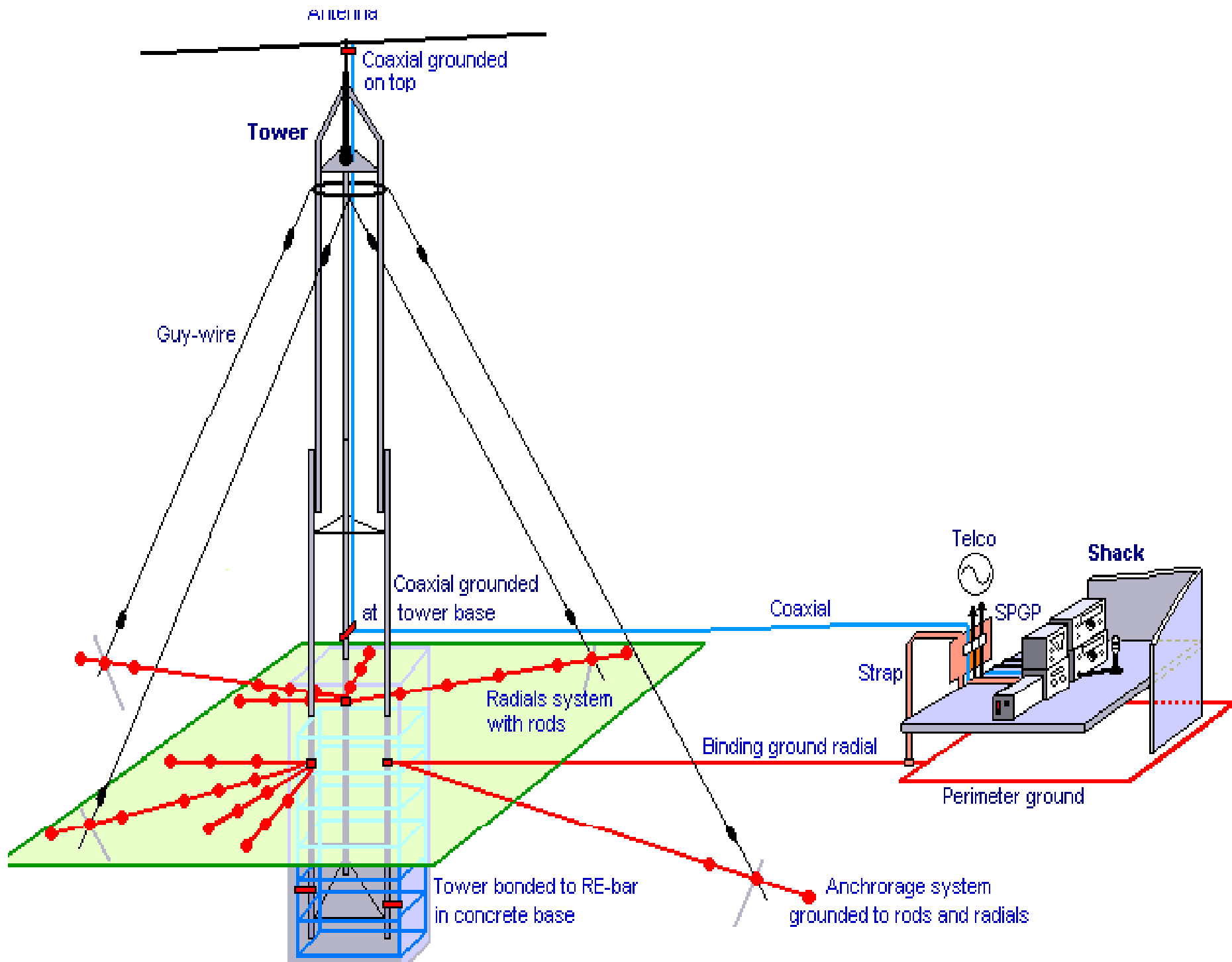
Freq. (MHz): 1.5 - 400	Protected Side Connector: UHF Female
RF Power (Watts): 125 - 2000 Watts	Surge Side Connector: IIHF Female
Application: HF test	Insertion Loss (dB): 0.1
Unit Imp. (Ohms): 50 Ω	Mounting: Bulkhead
Throughput Energy (μ J): $\leq 10000.0000 \mu$ J	Turn On Voltage (Volts): +/- 600 V
Throughput Voltage (Volts): ≤ 900 Vpk	VSWR: 1.2:1
Weatherized: No	



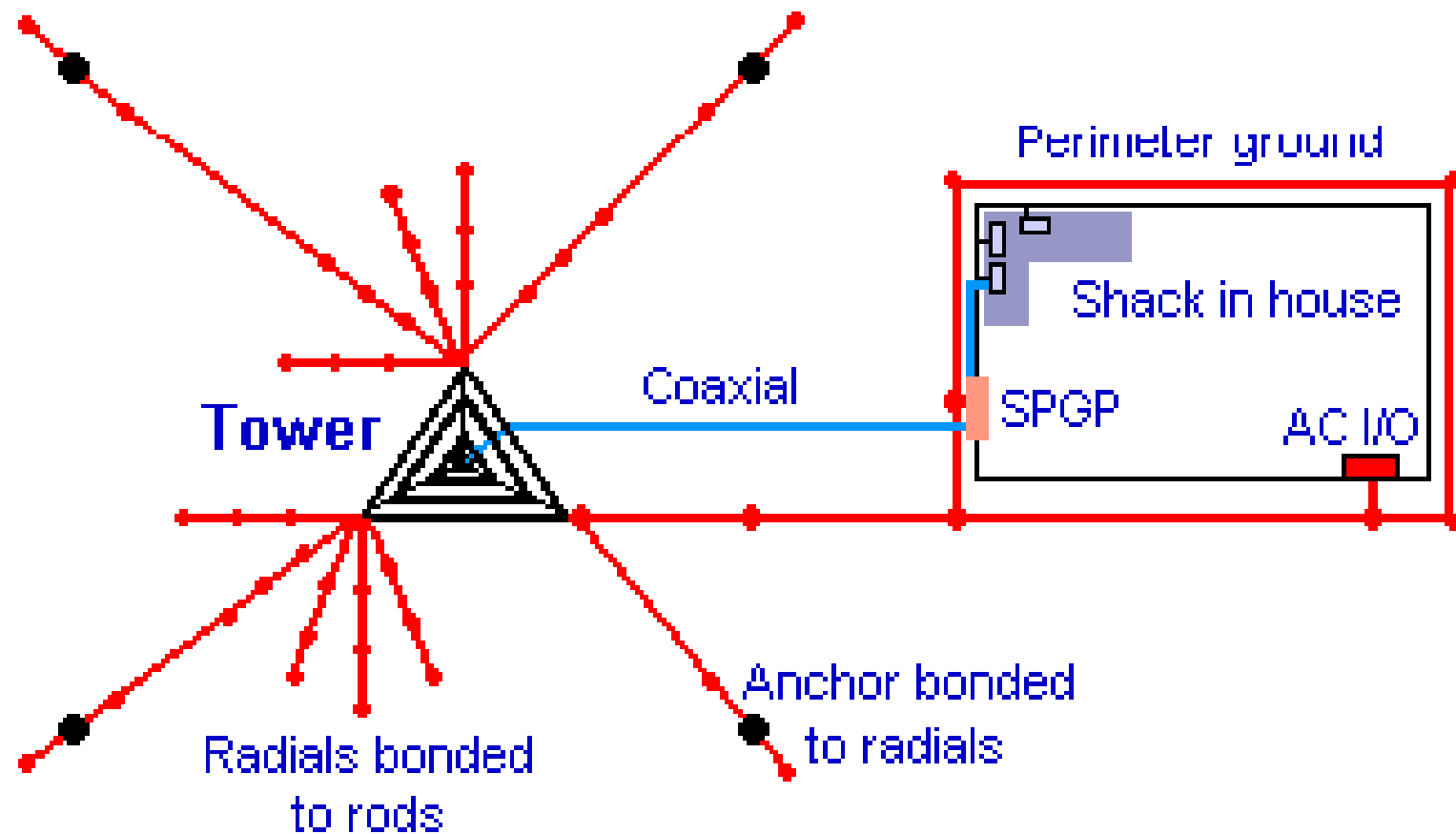


- * Common ground point
- * Fuse or circuit breaker
- * Safety interlock on high voltage supplies
- * Everyone in your house should know how to shut off the power

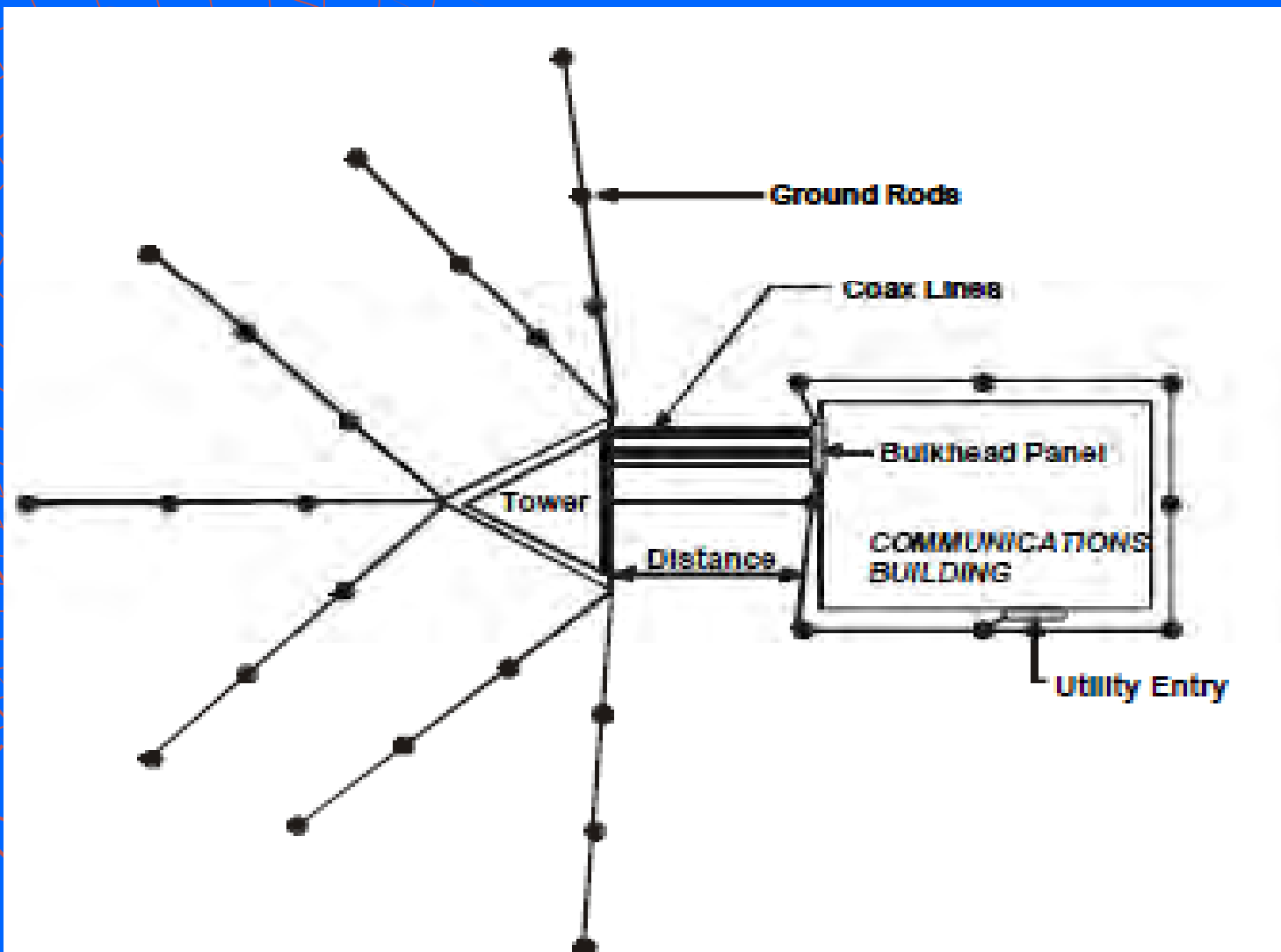




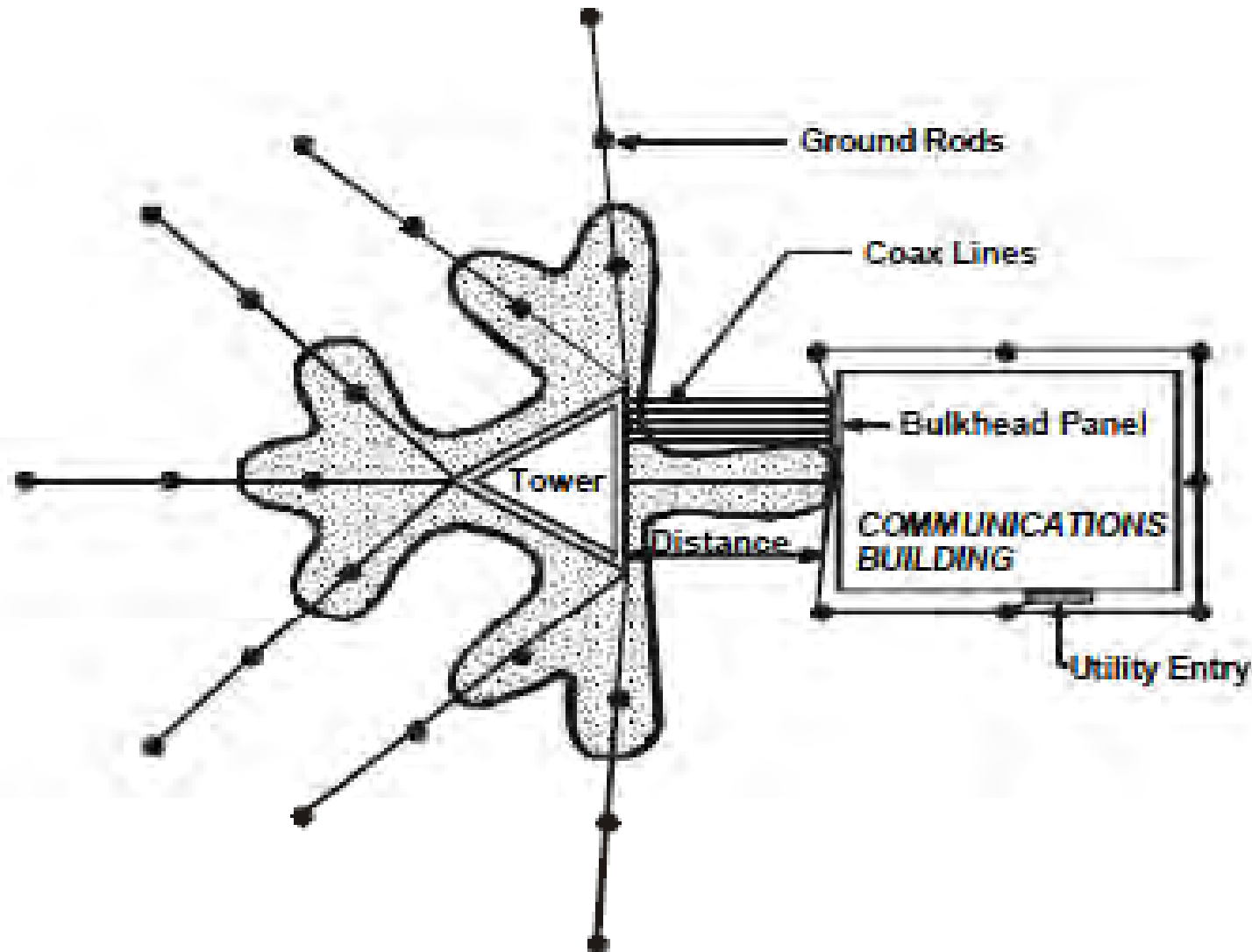
Grounding system viewed from top



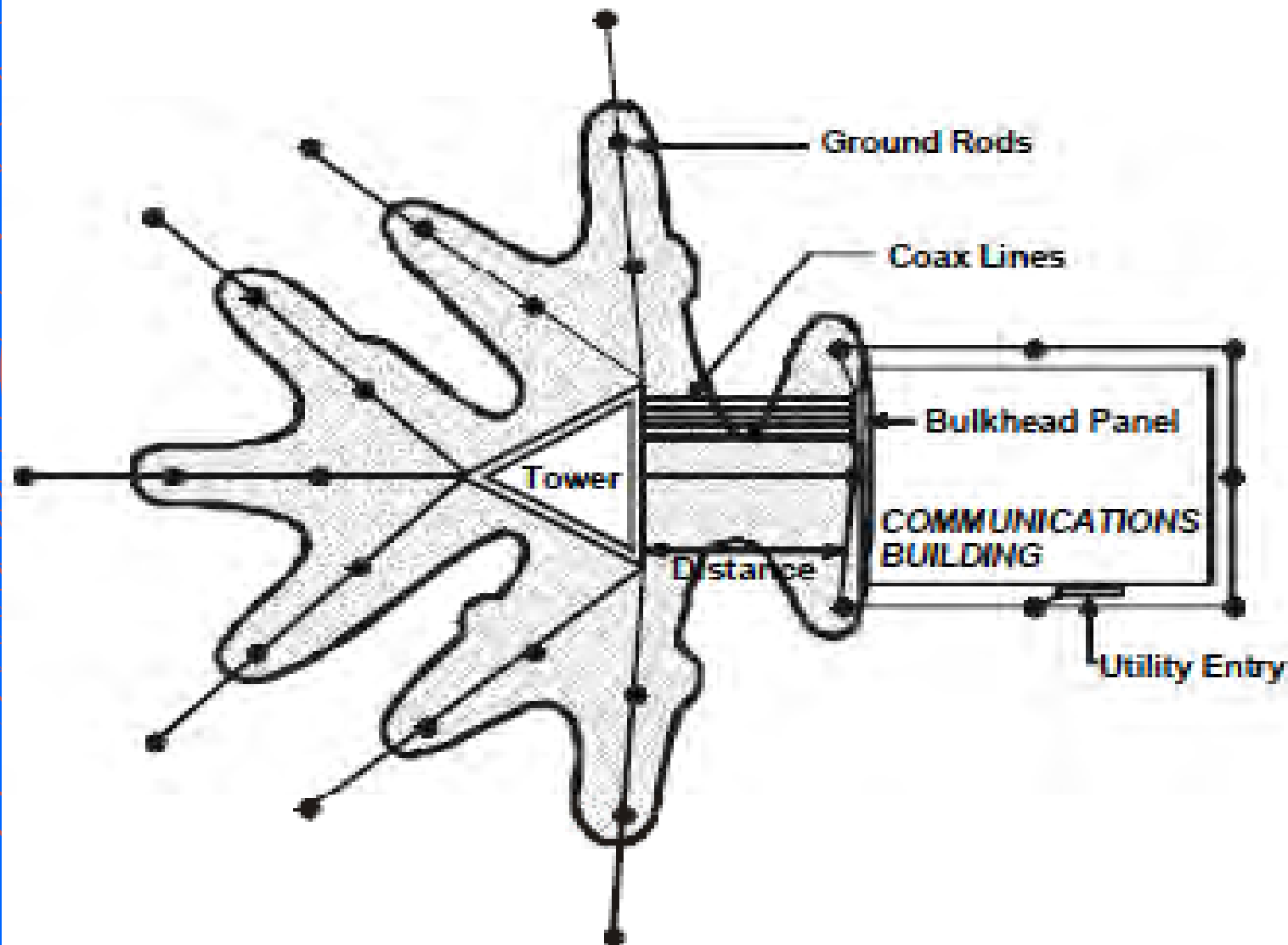
Lightning strike ground saturation before strike @ $t = -$



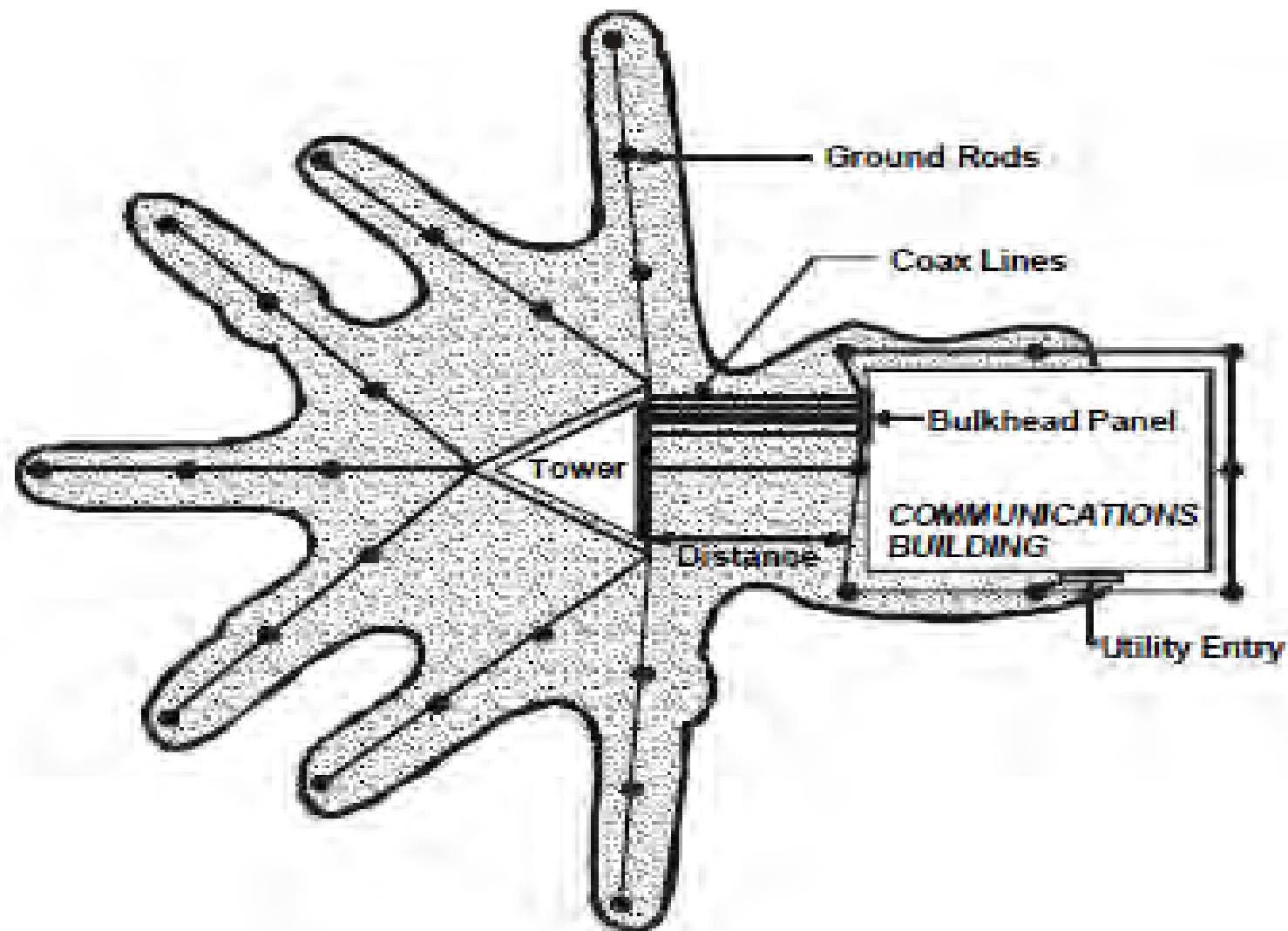
Lightning strike ground saturation immediately after incident @ $t = +$



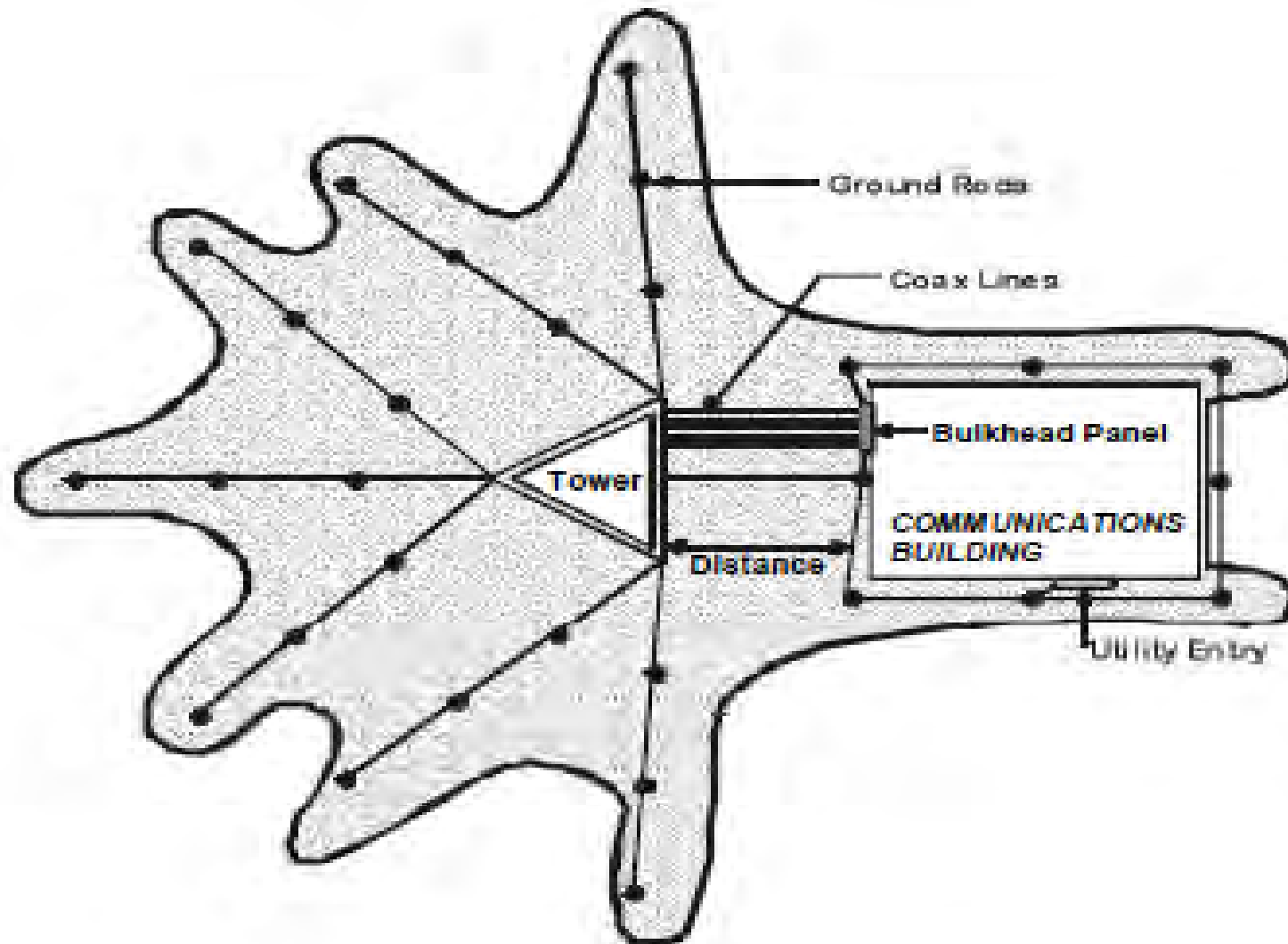
Lightning strike ground saturation immediately after incident @ $t = 2+$



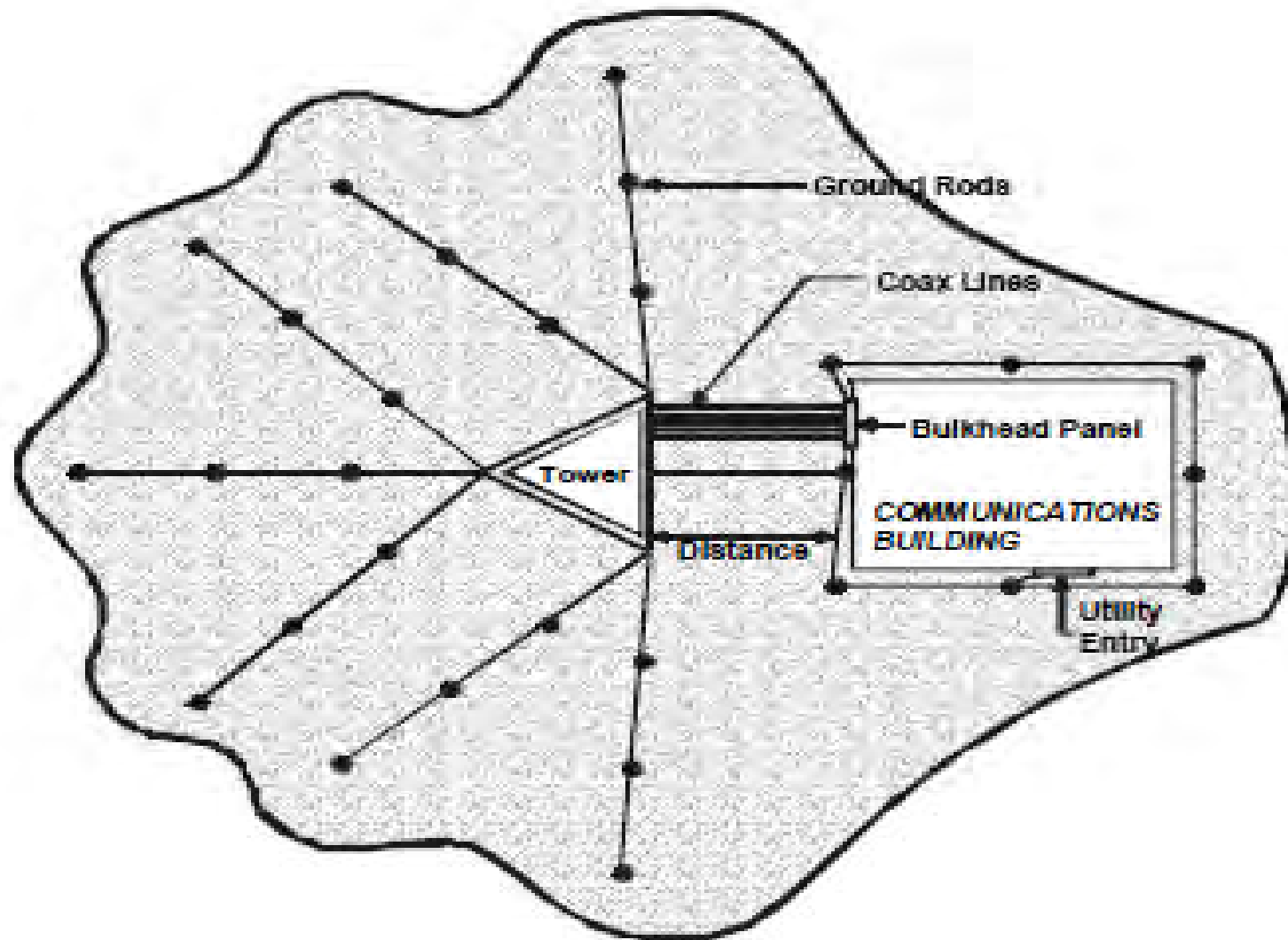
Lightning strike ground saturation immediately after incident @ $t = 3+$



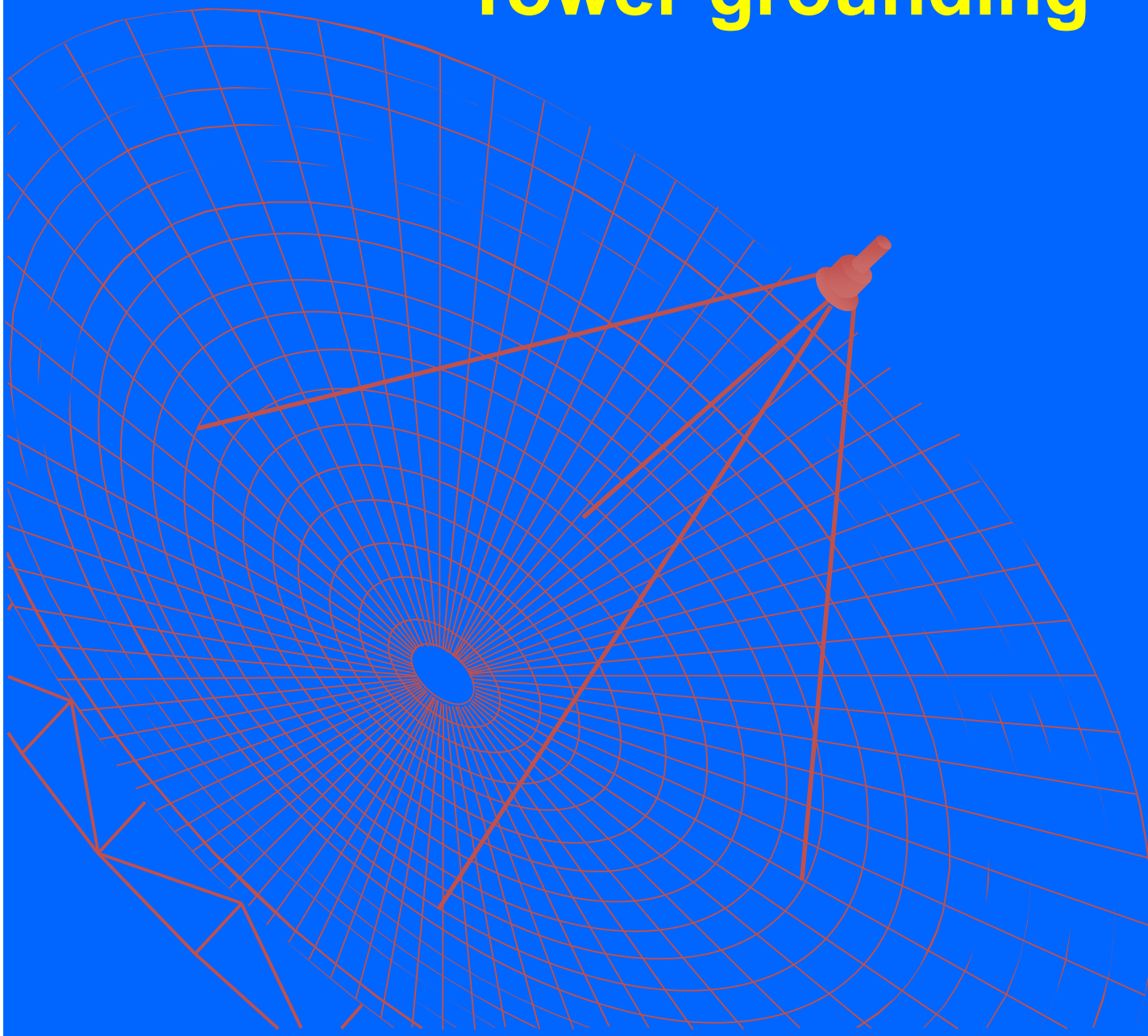
Lightning strike ground saturation immediately after incident @ $t = 4+$



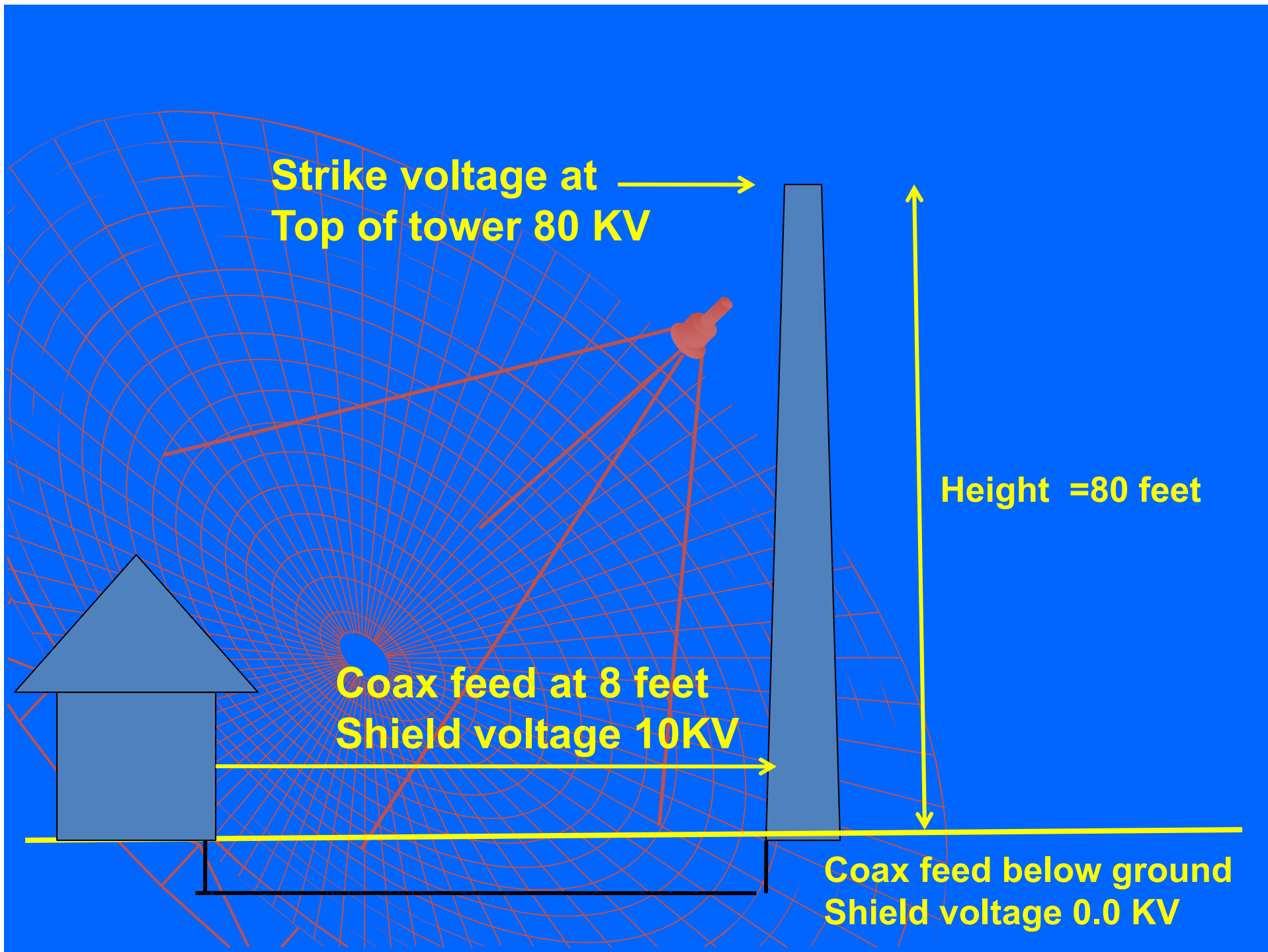
Lightning strike ground saturation immediately after incident @ $t = 5+$

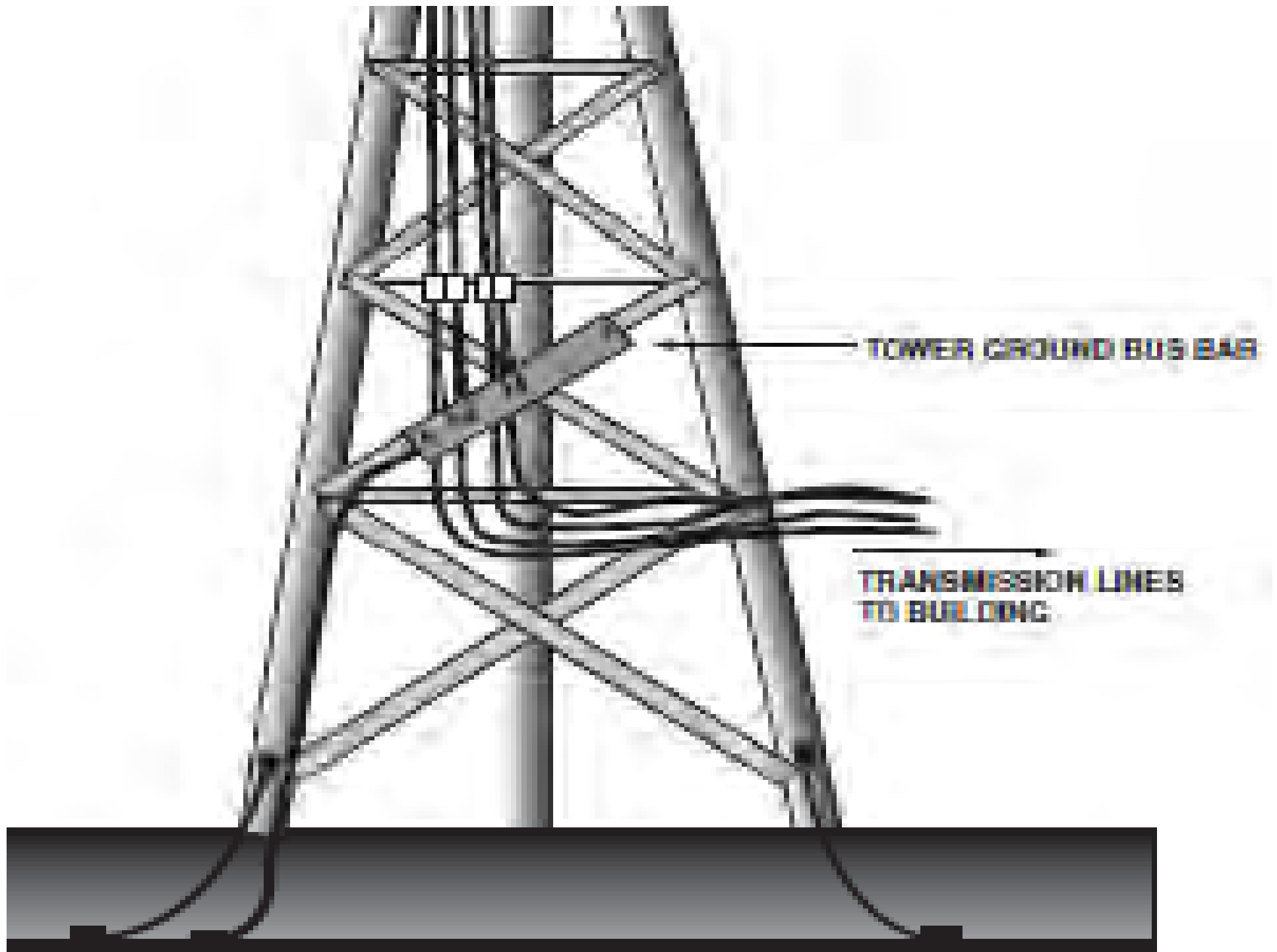


Tower grounding









External building ground ring

- #2 AWG for other than Florida lightning
- #1/0 AWG for Florida lightning
- Building ground rings bonded together minimum #1/0 AWG (Florida)
- Ends of the conductor exothermic weld or listed irreversible high-compression connector

Feed Lines and Grounding

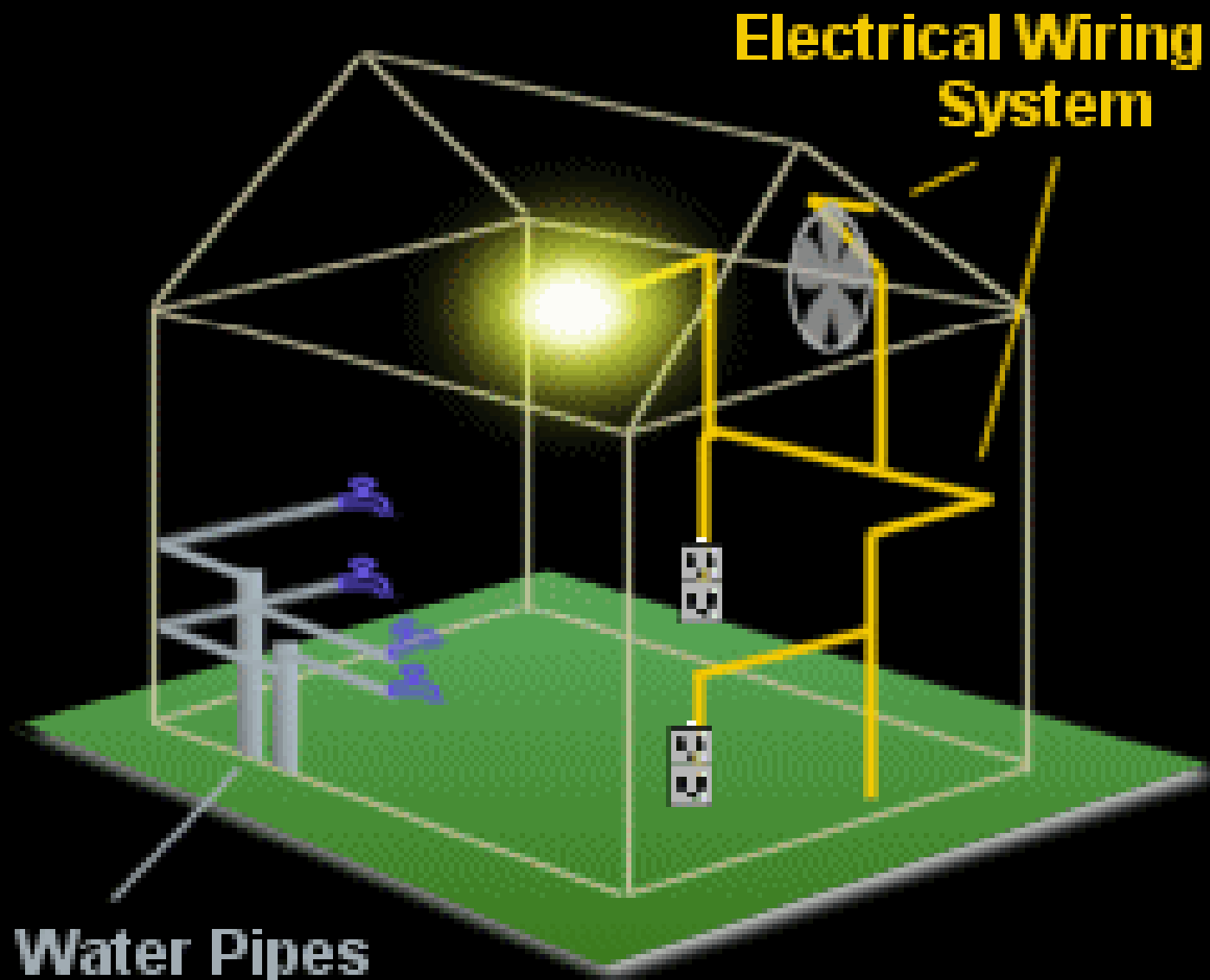
- Coax lines -- in underground conduit rather than going overhead.
- In-line surge protectors on coax and shunt protectors on rotator cable at the base of the tower.
- Ground rods at each tower leg and additional rods spaced at twice their length and all tied together
- Perimeter ground and the AC service 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

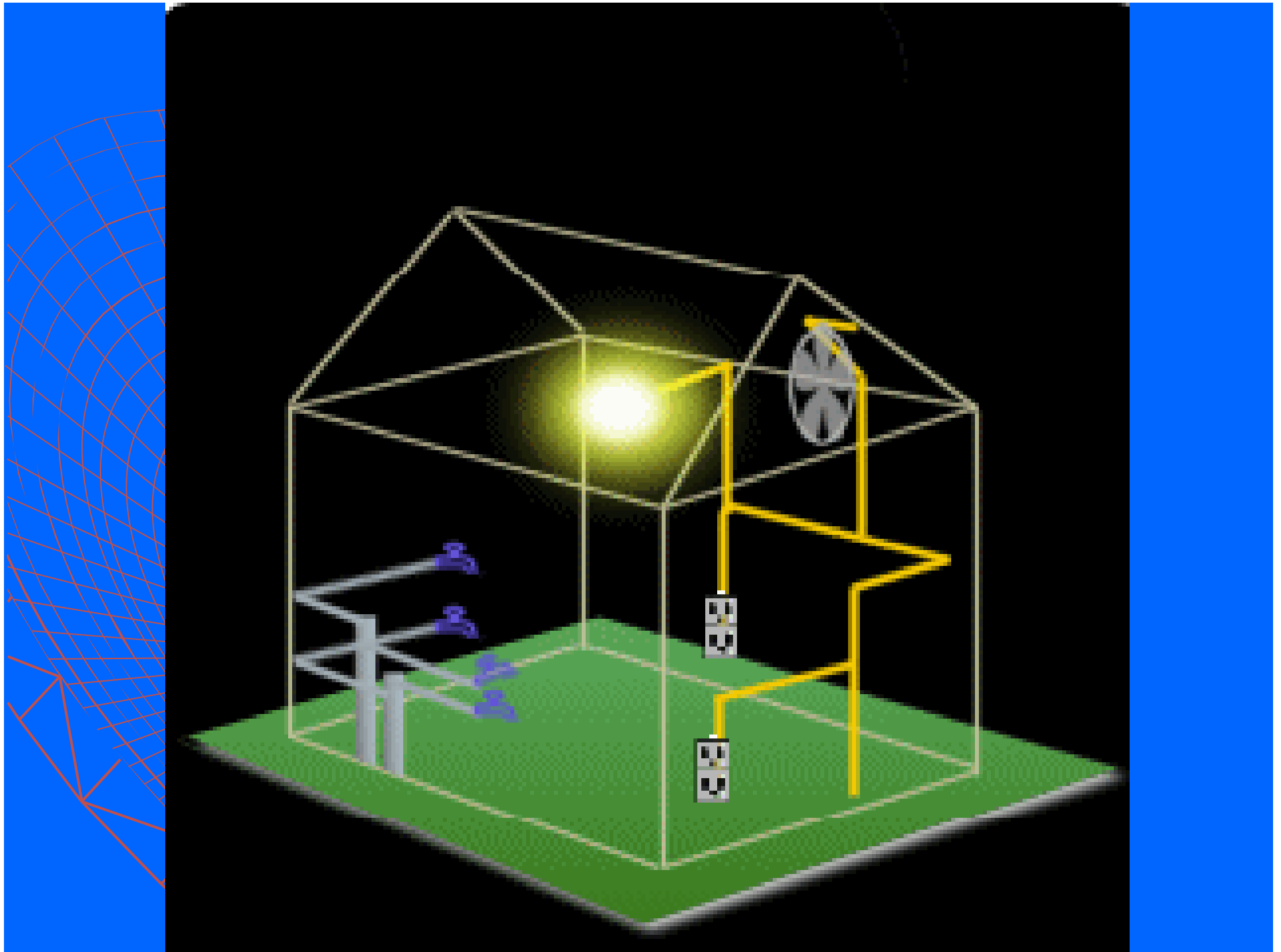


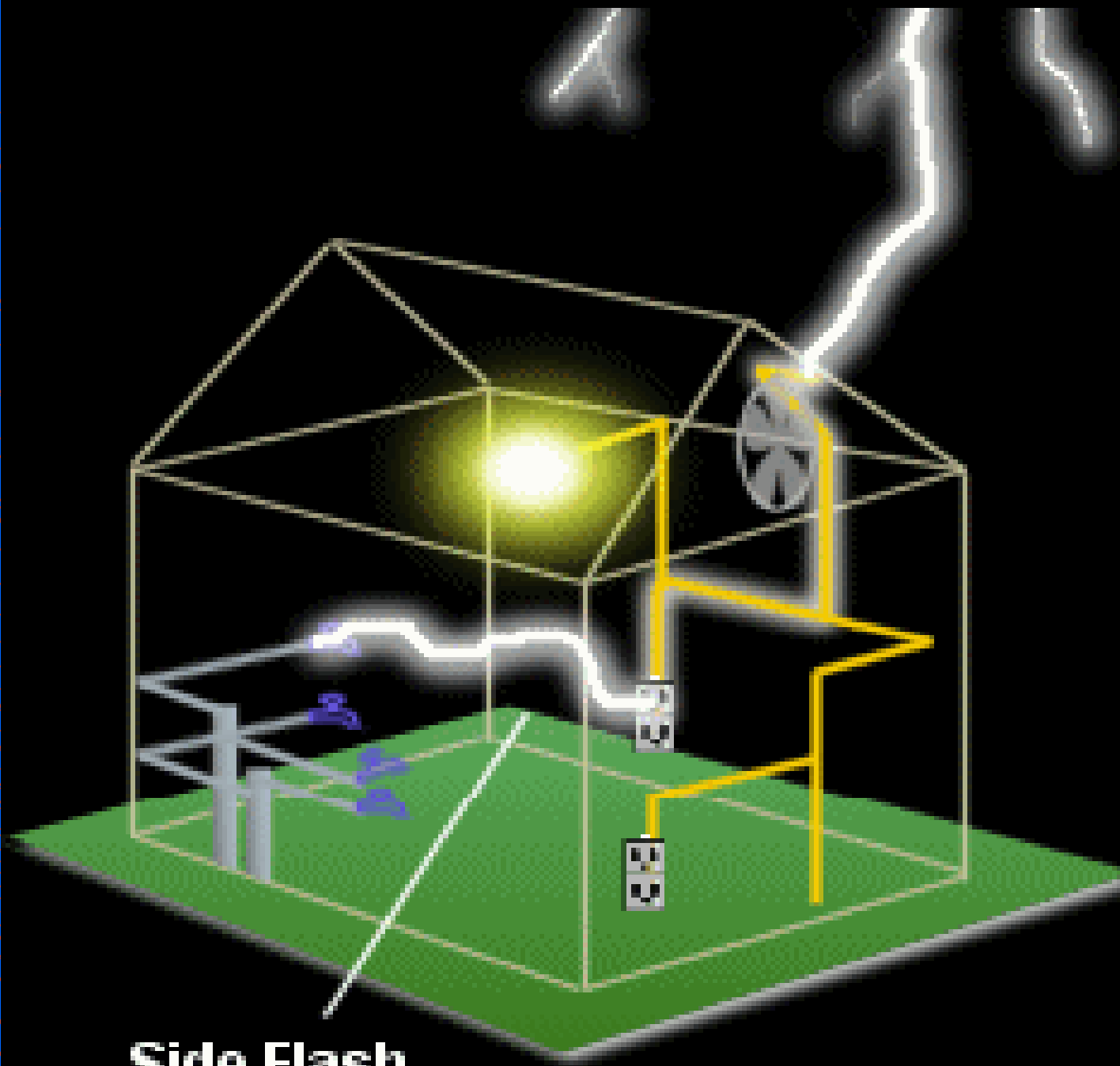




Unprotected Structure

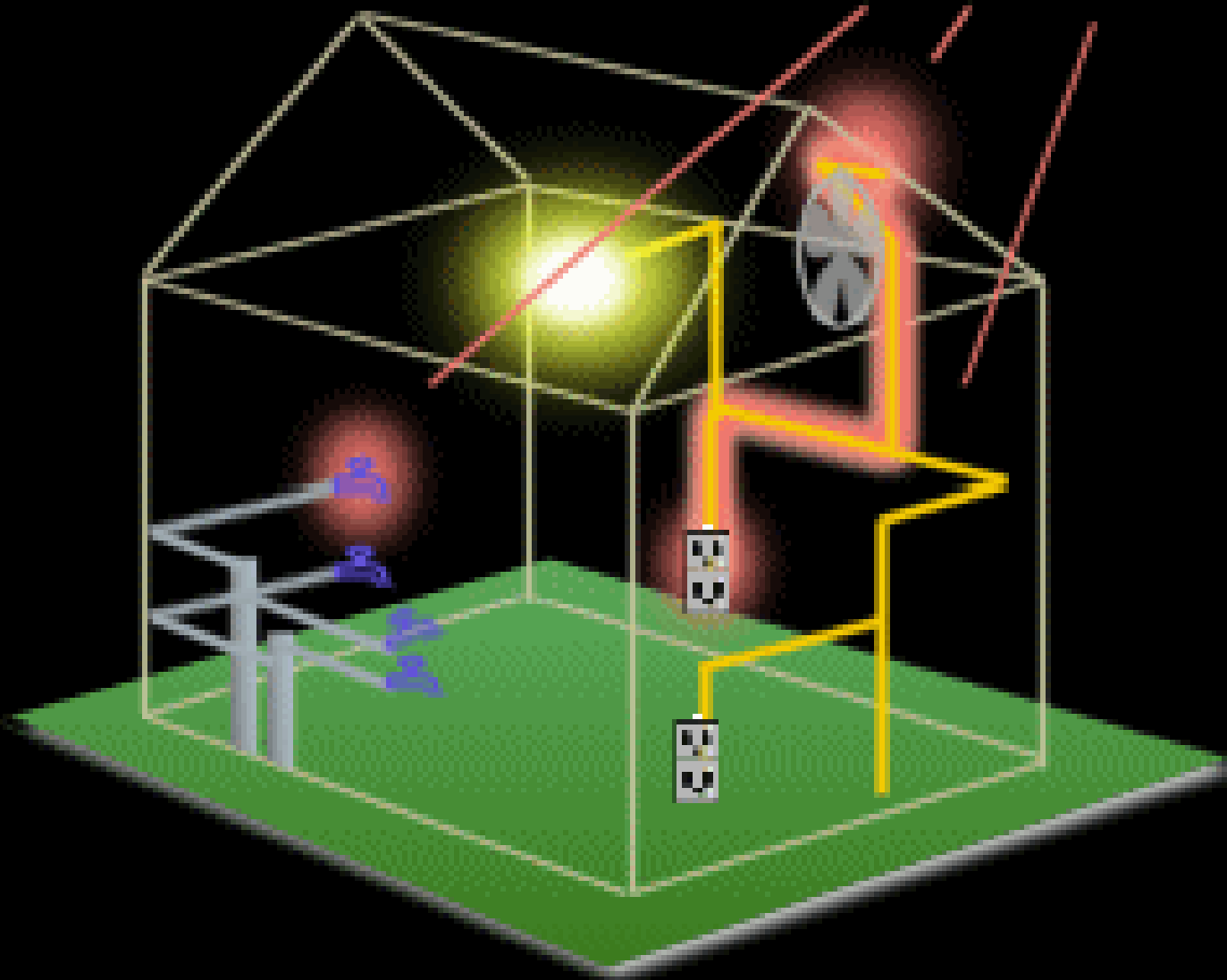






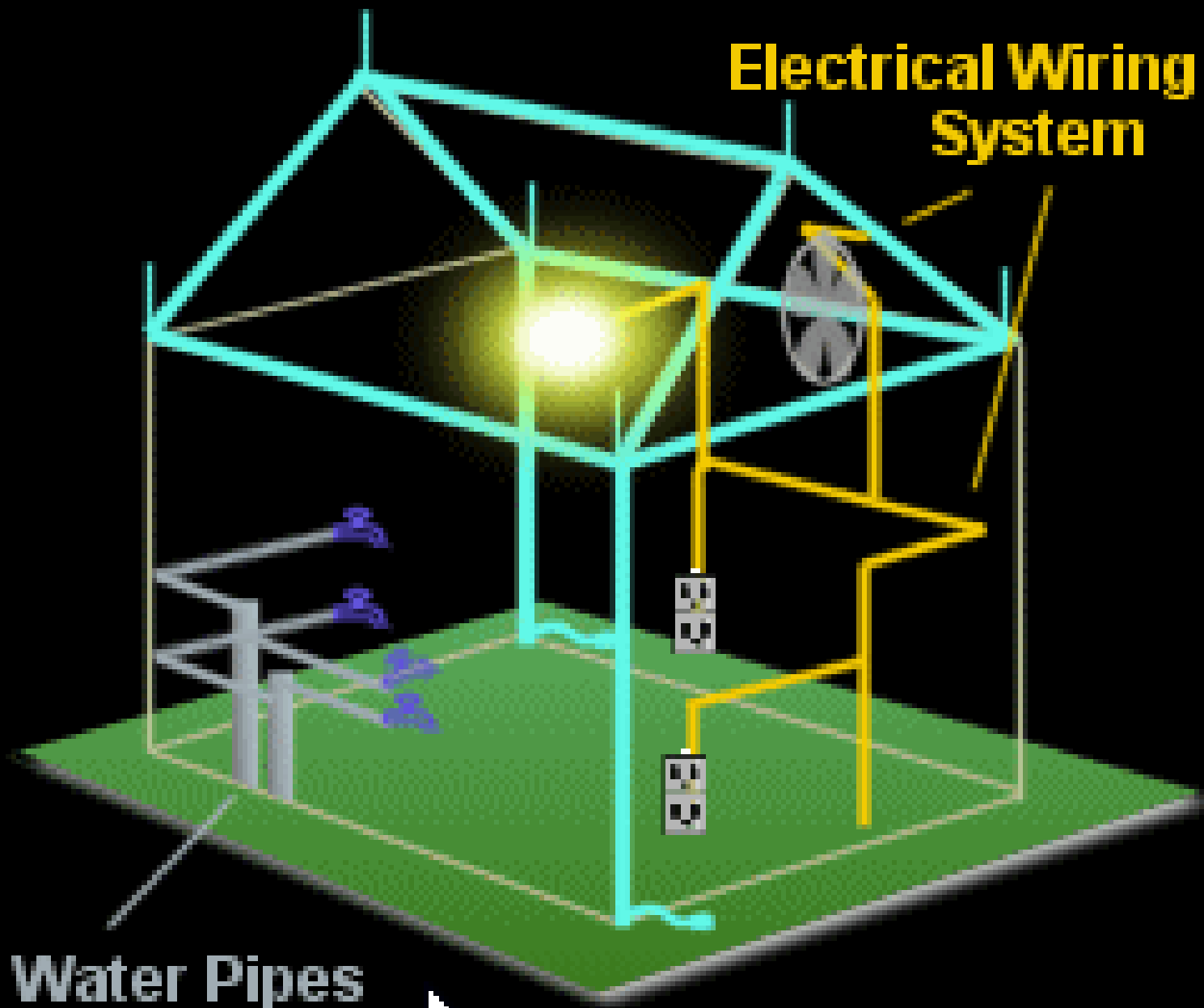
Side Flash

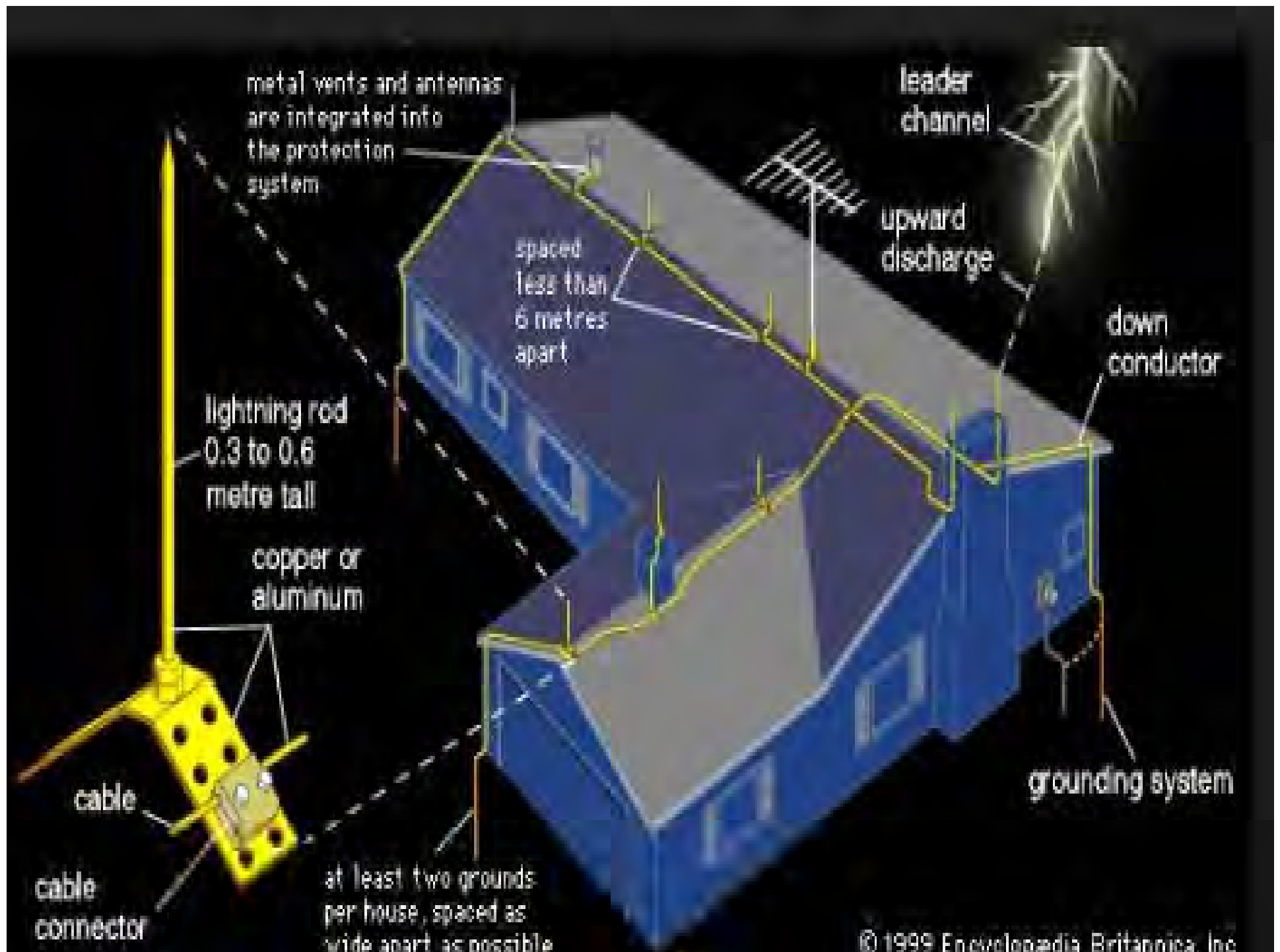
Fire Danger



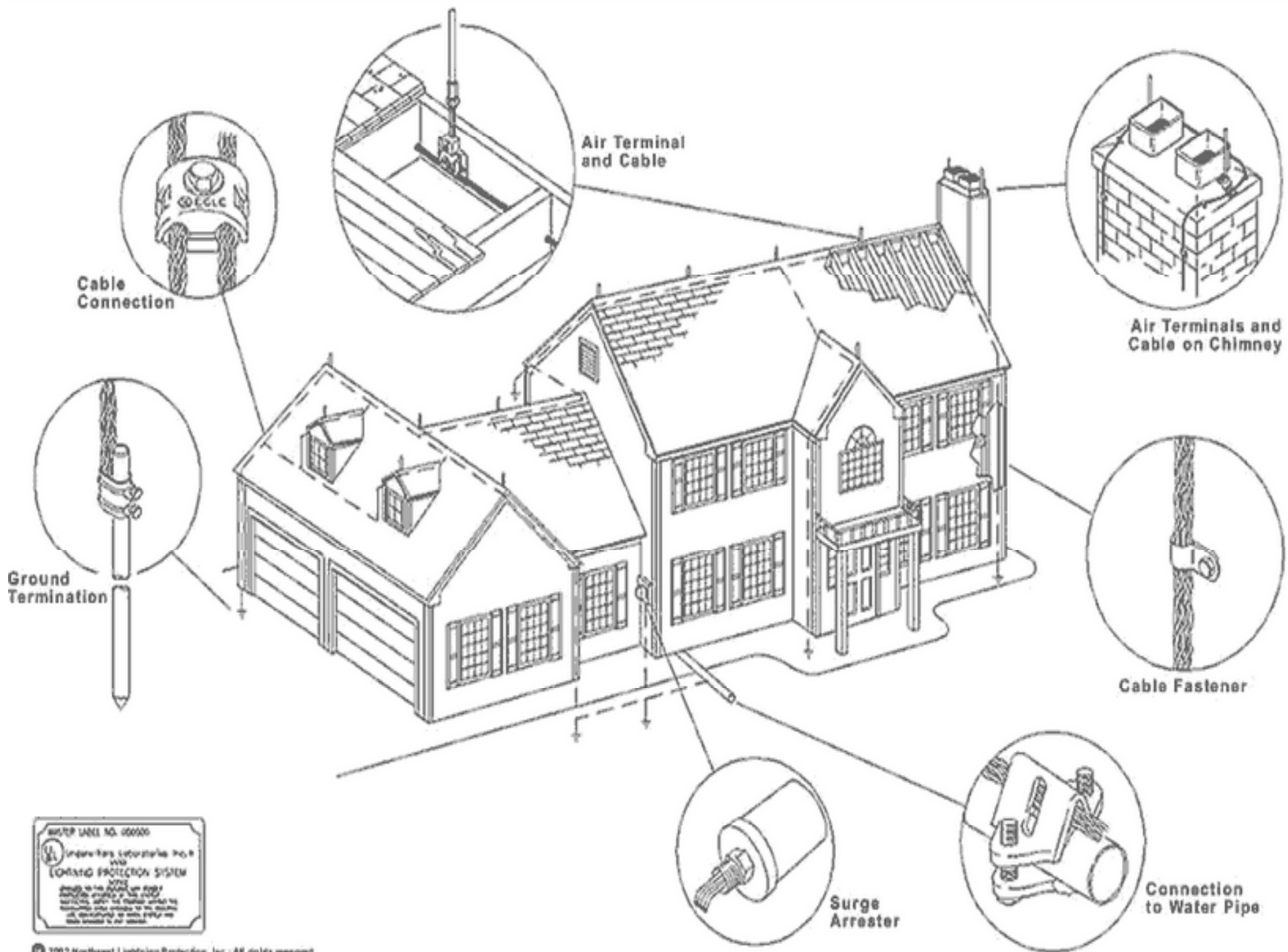
c. 2001 wvlightning.com

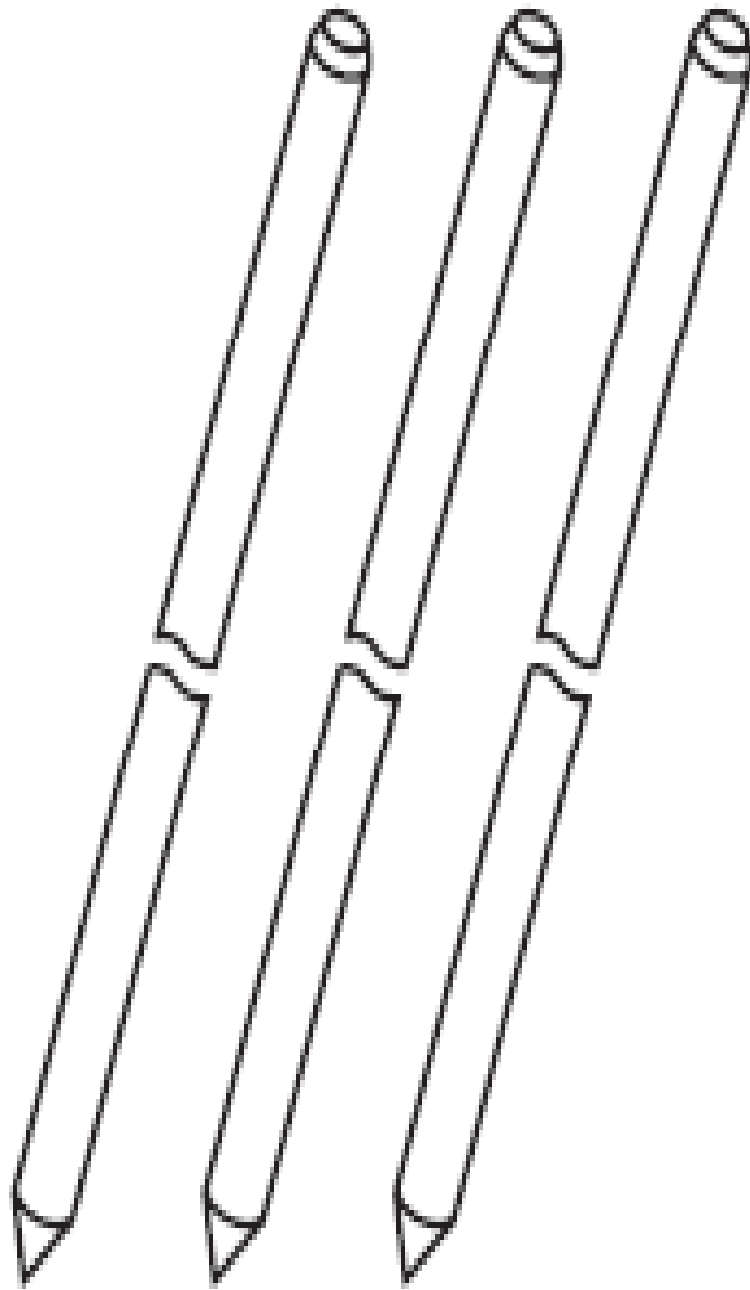
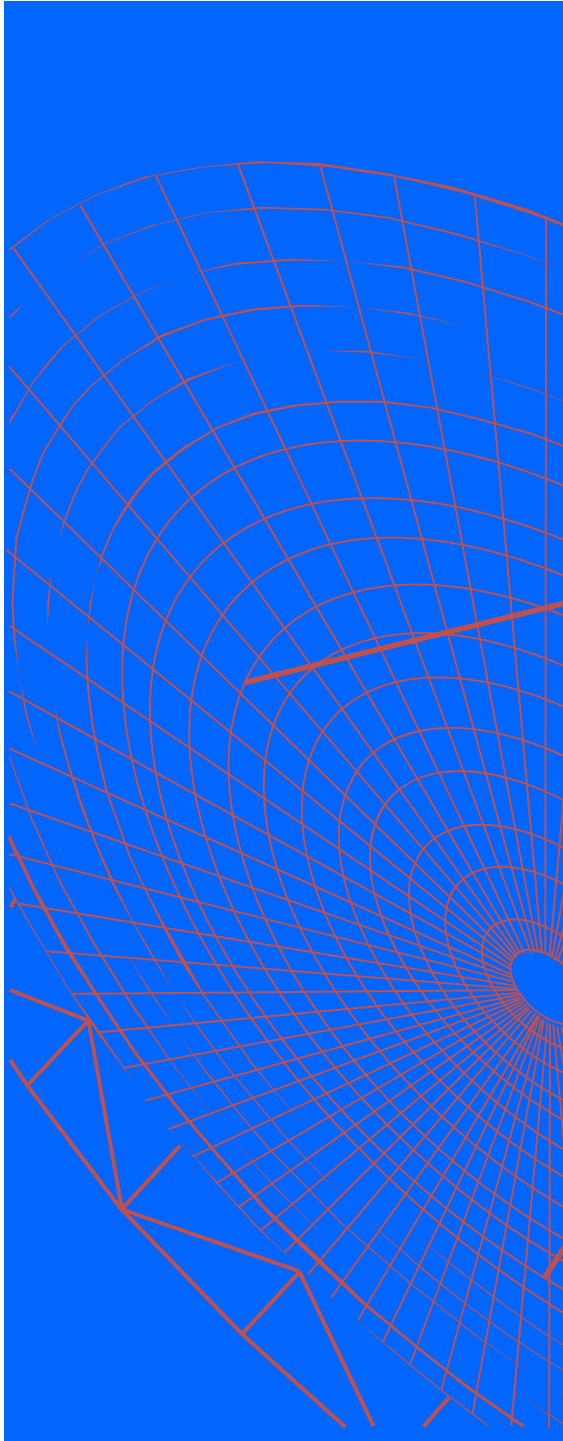
Protected Structure





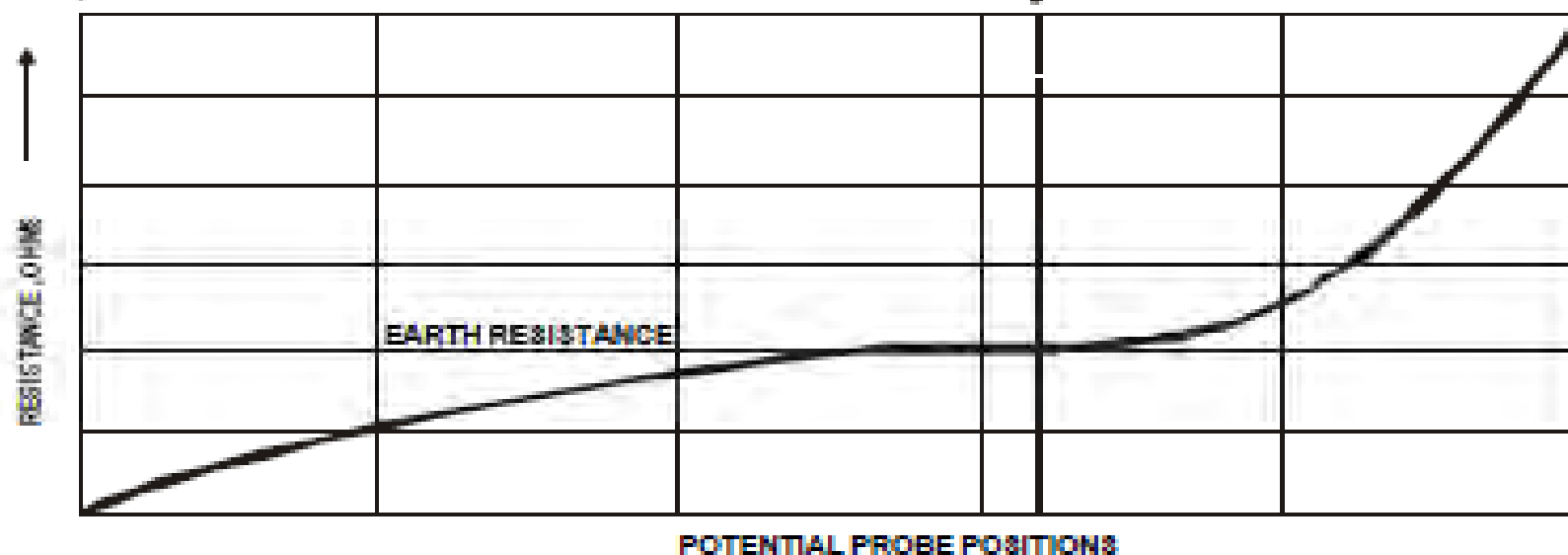
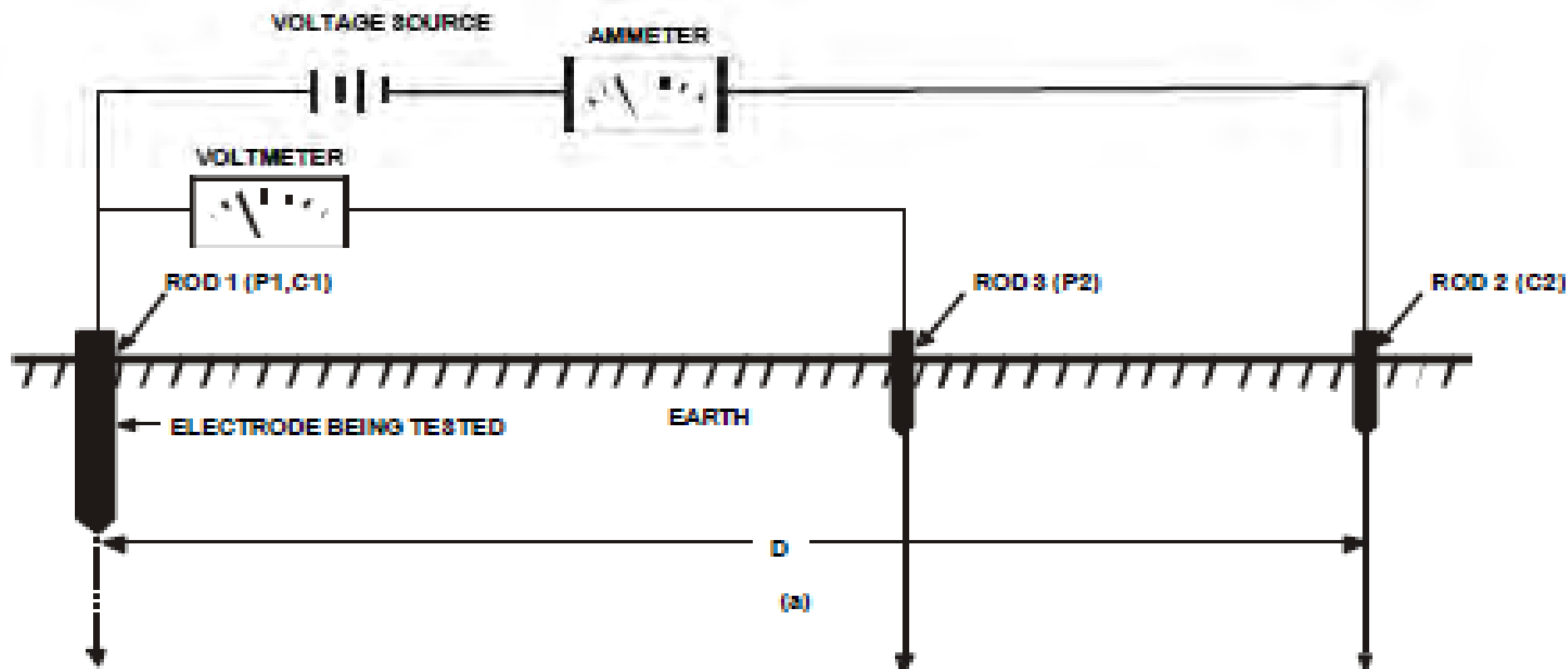




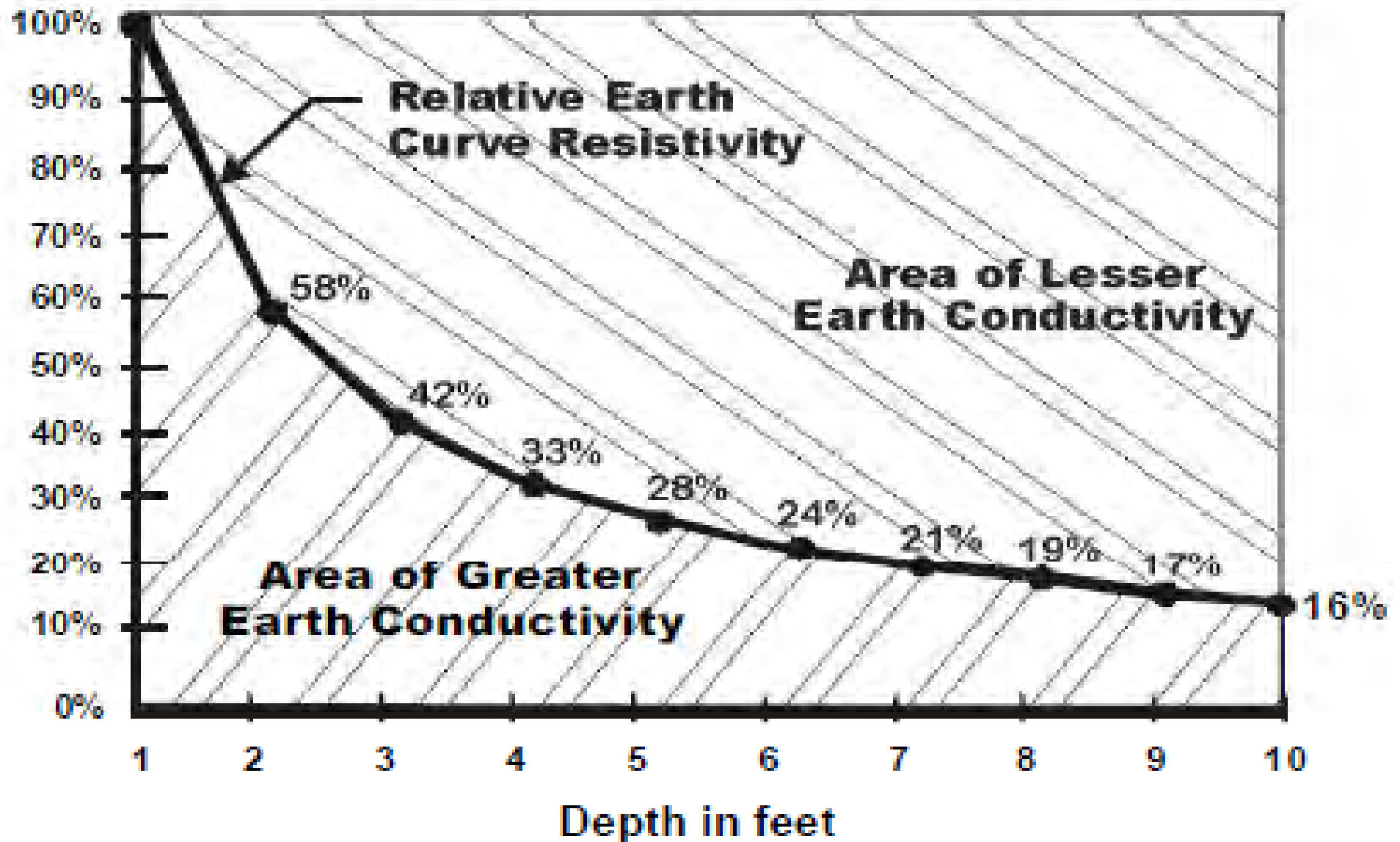


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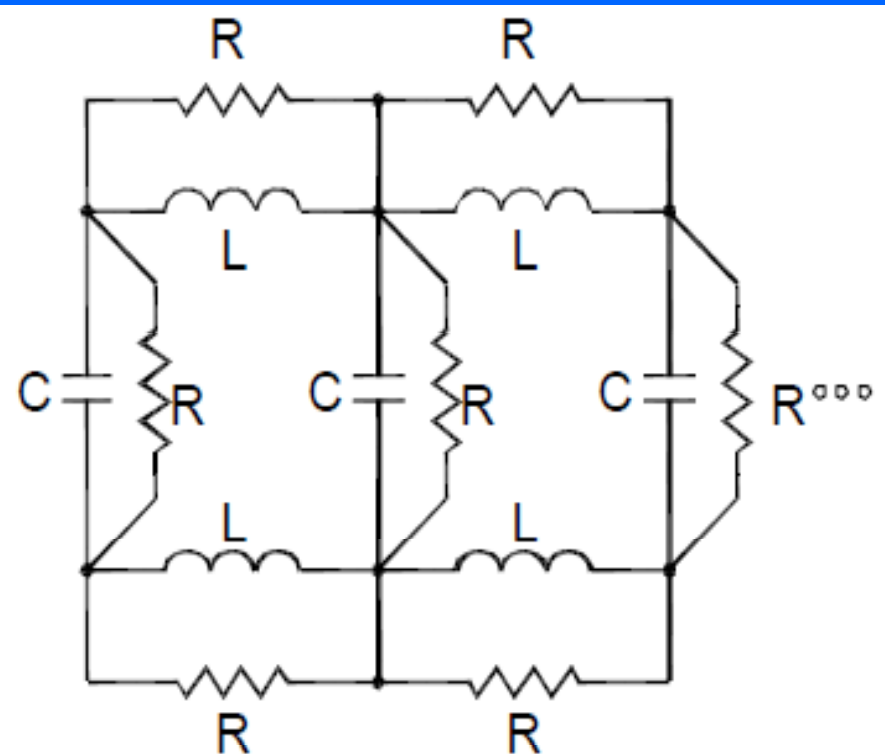
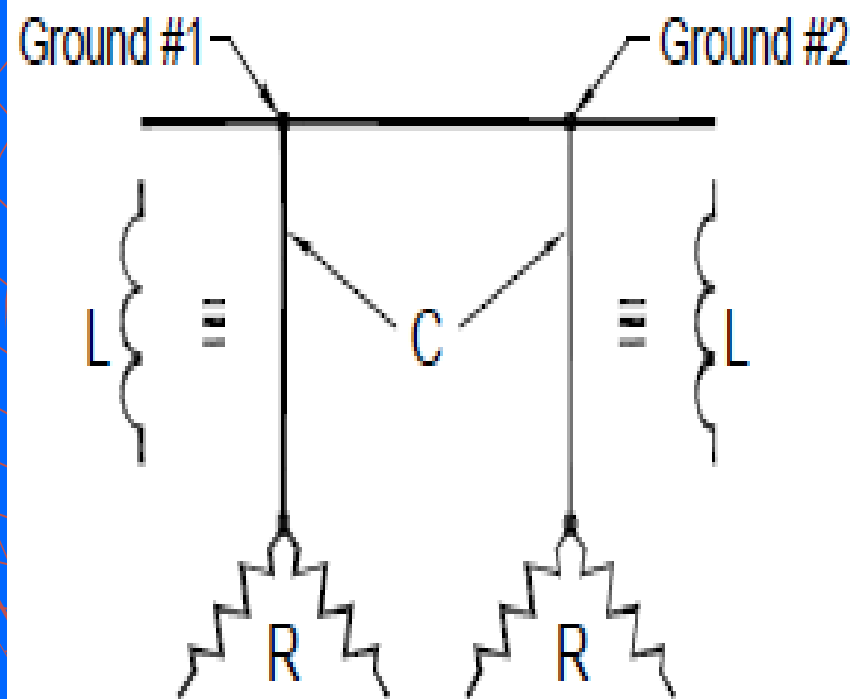


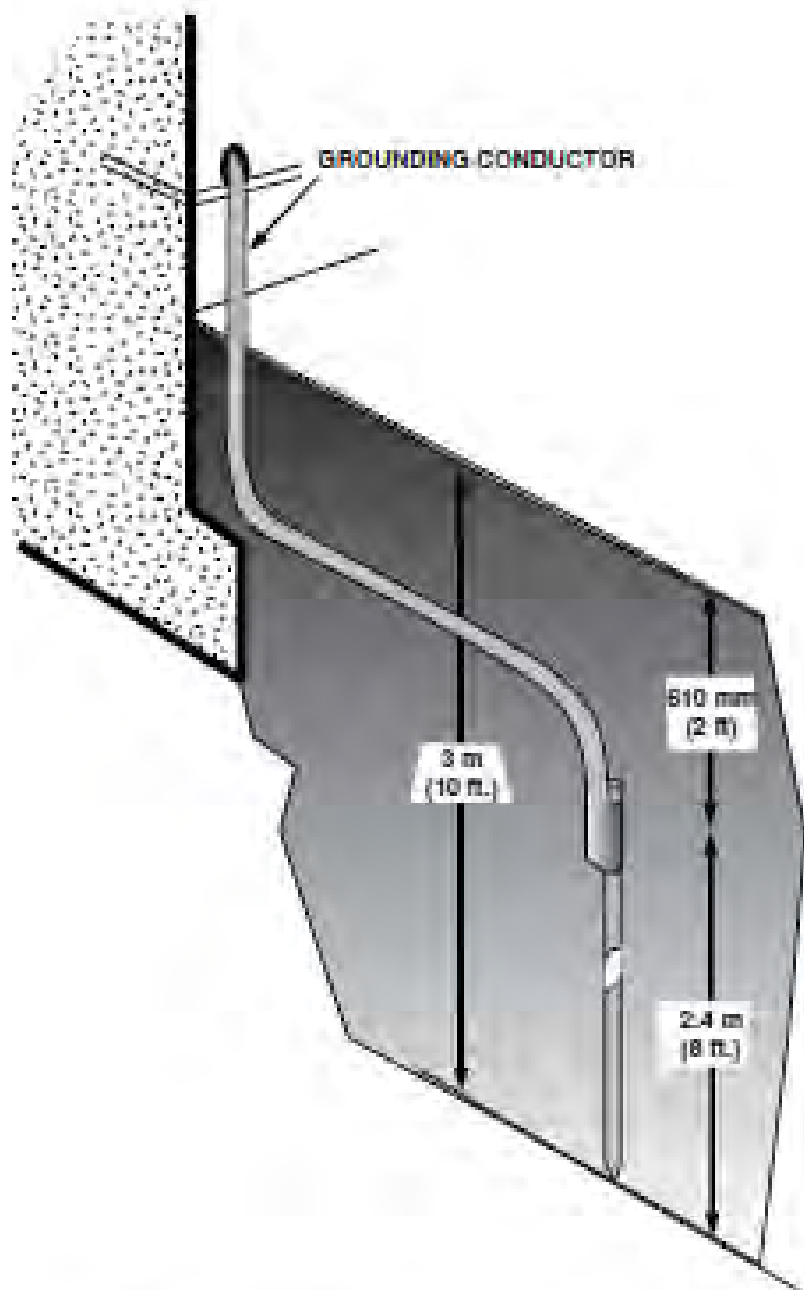


Ground system measuring

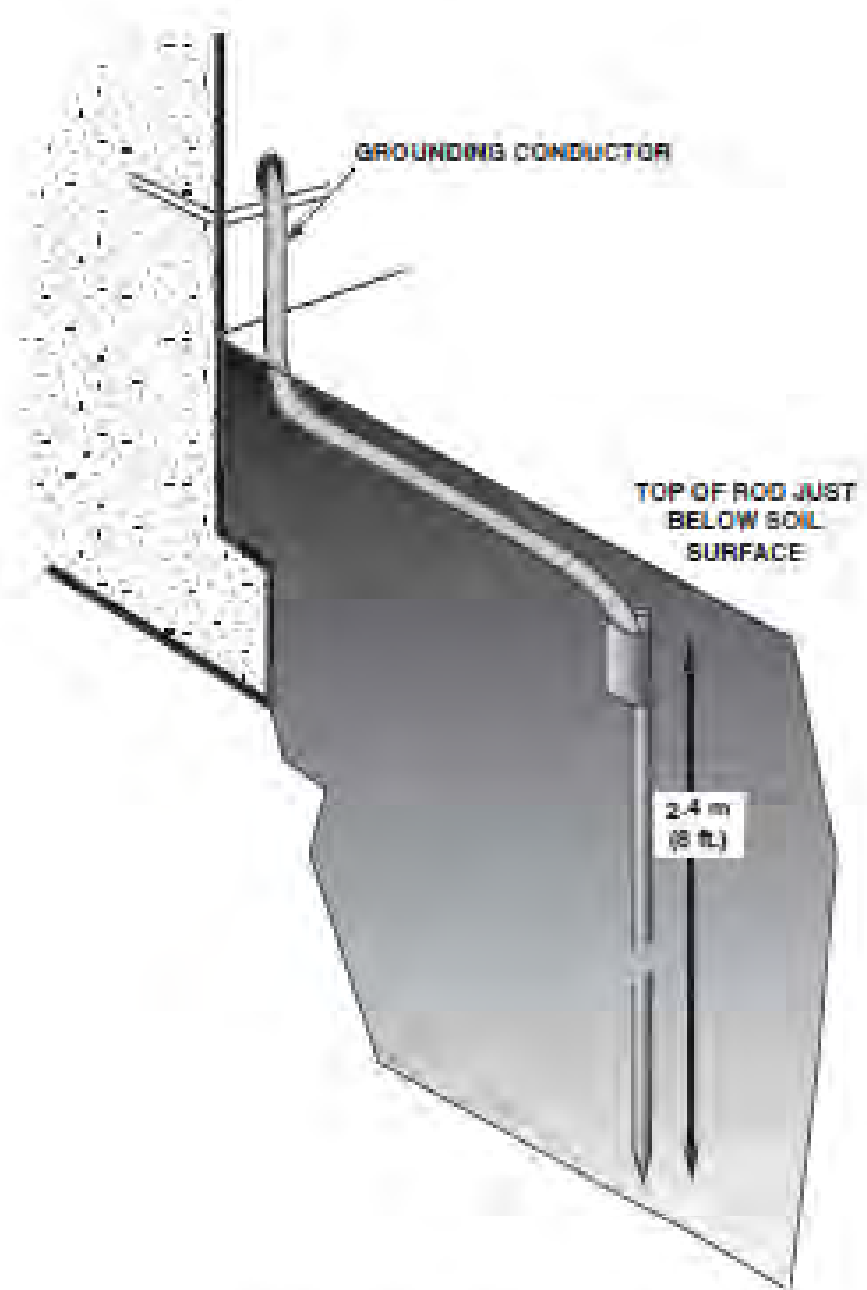


Ground stakes

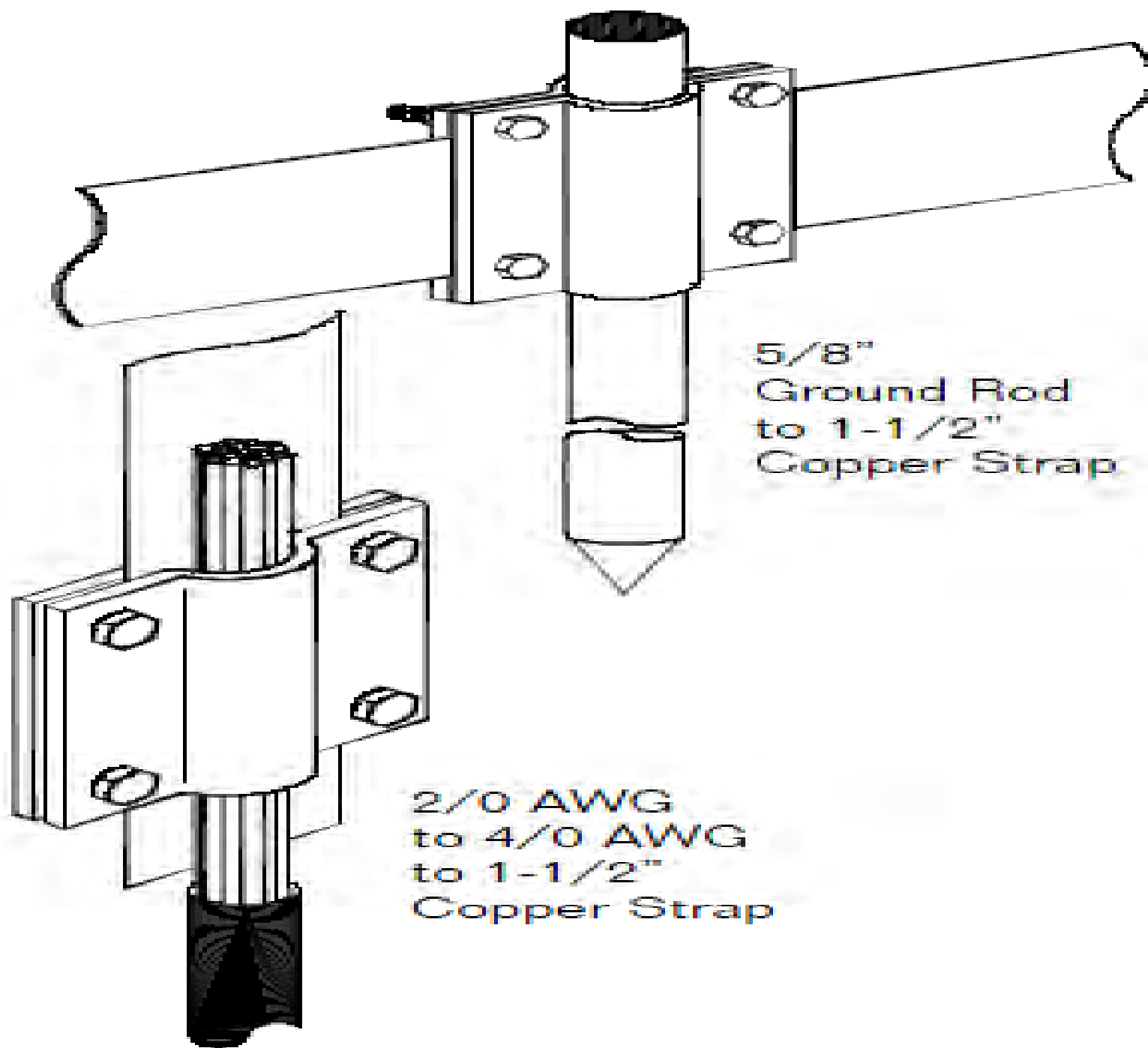




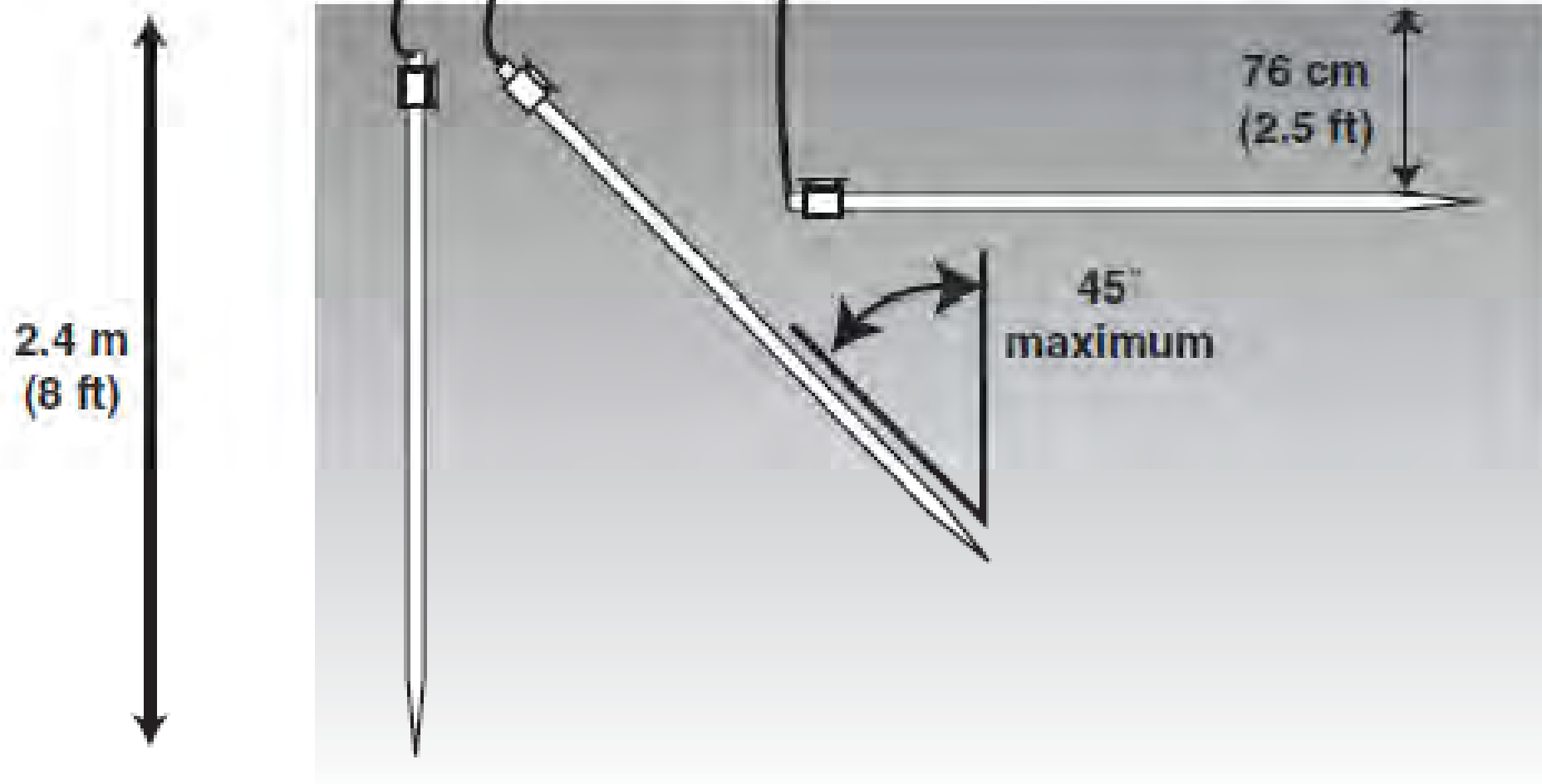
RECOMMENDED DEPTH

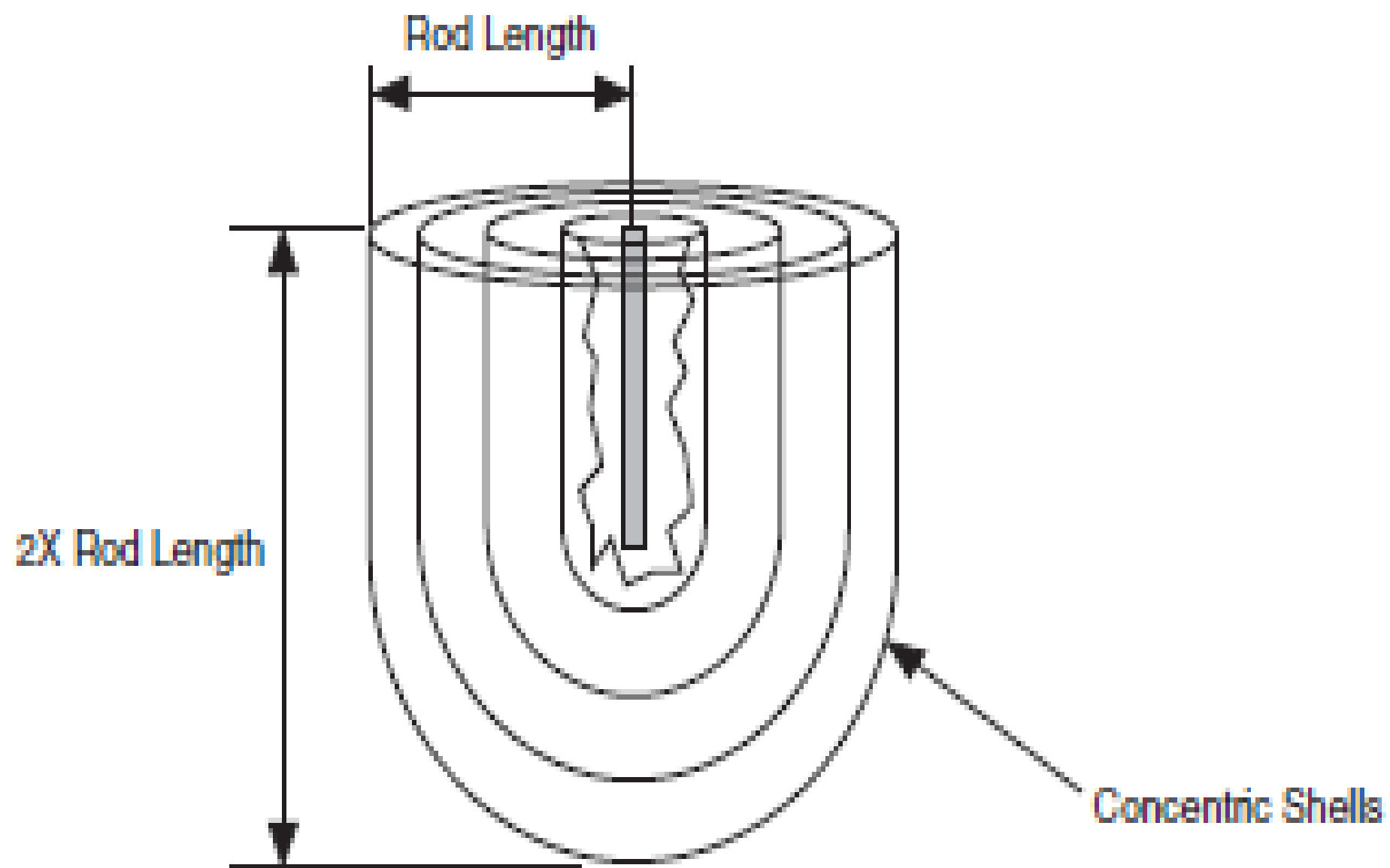


MINIMUM DEPTH

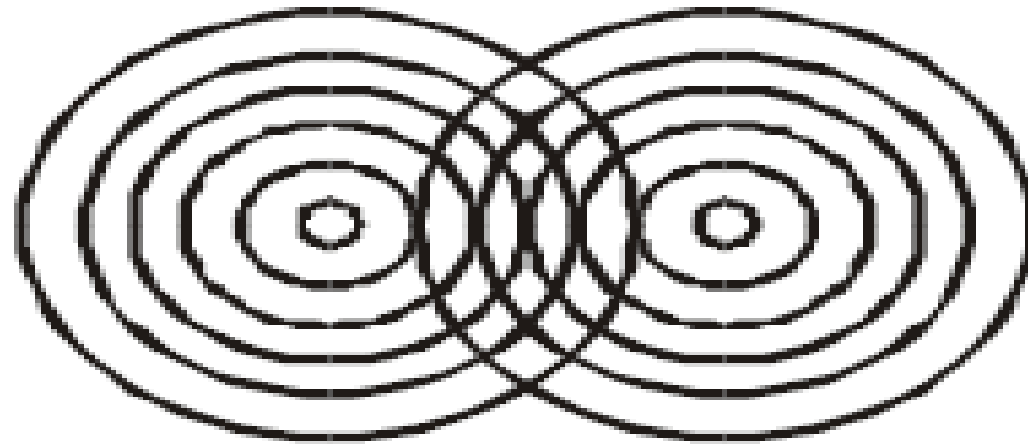


BURIED GROUNDING ELECTRODE CONDUCTORS

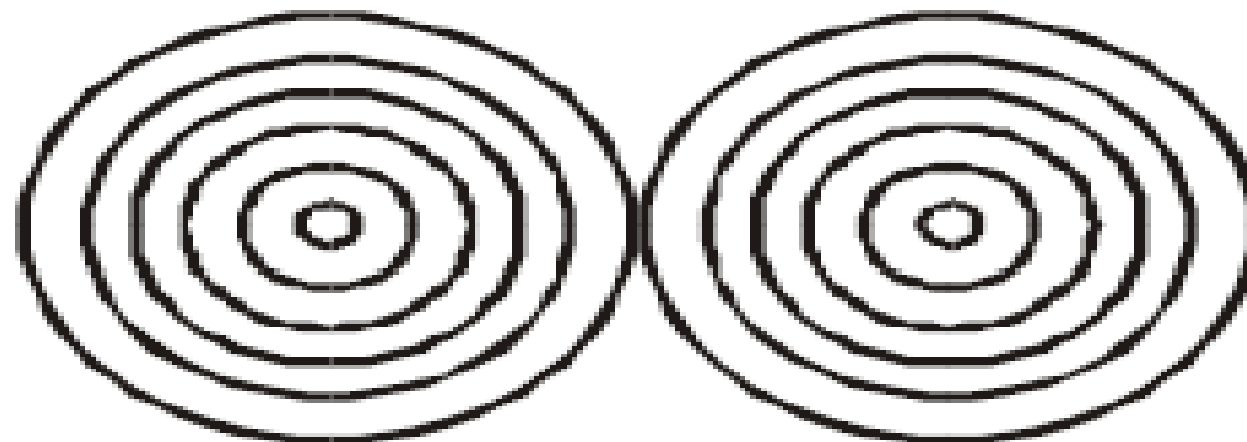


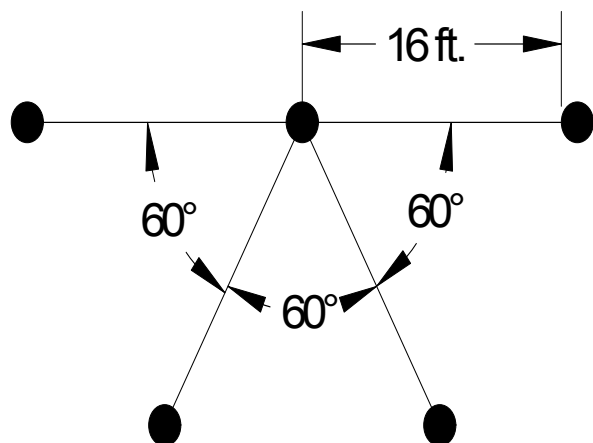


Incorrect Spacing

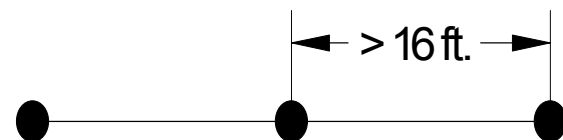


Correct Spacing

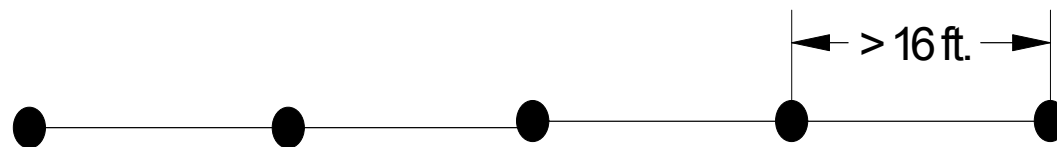




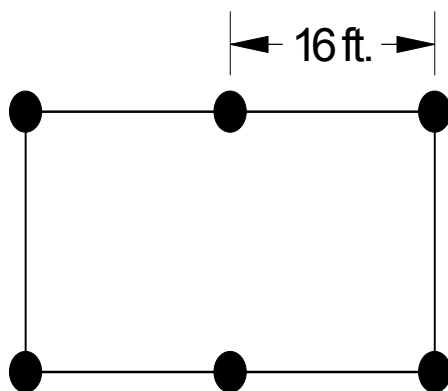
Star Grounding Pattern
~ 5 ohms



Horizontal Array Pattern
~ 10 ohms



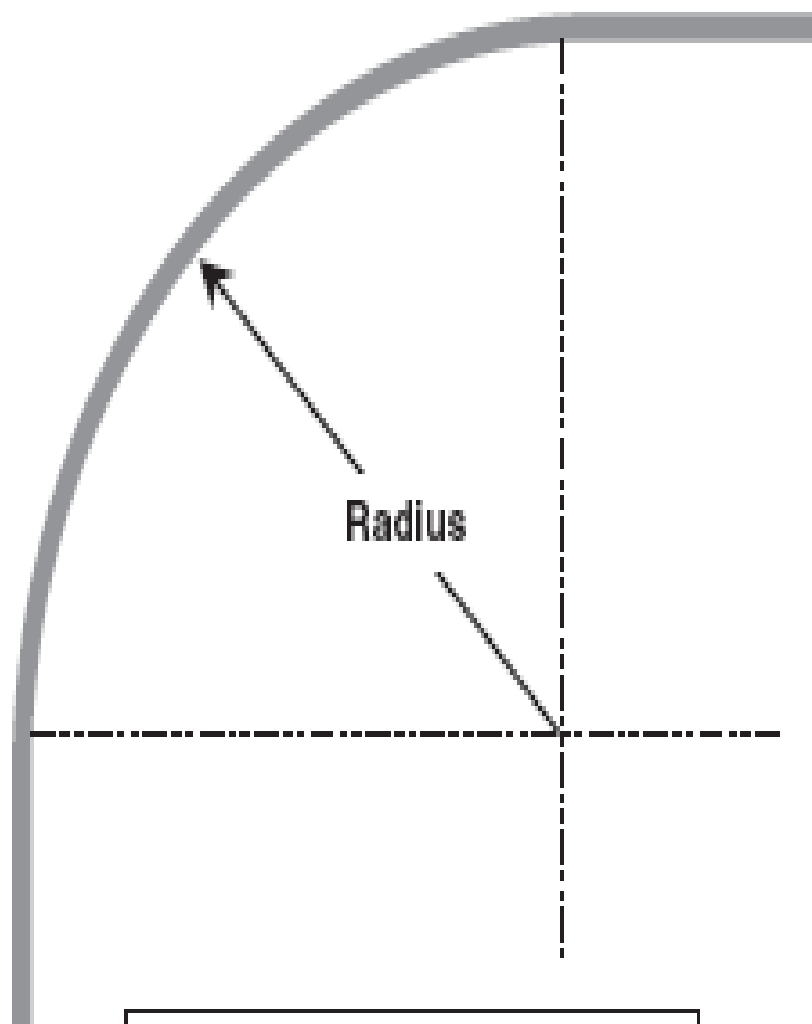
Horizontal Array Pattern
~ 5 ohms



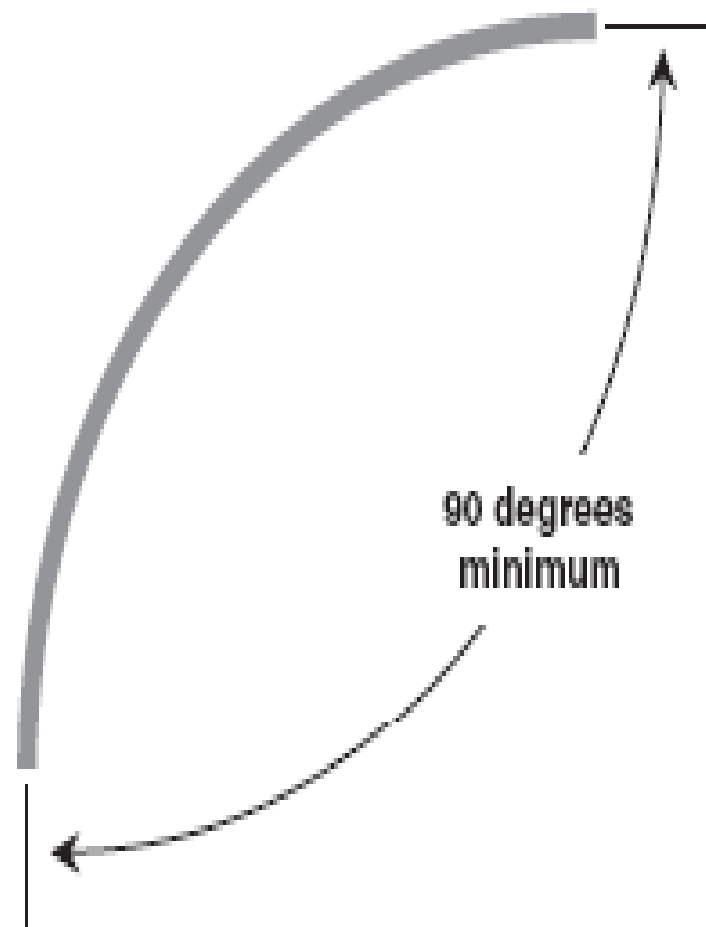
Perimeter Grounding Pattern



Single Ground Rod
~ 25 ohm per NEC

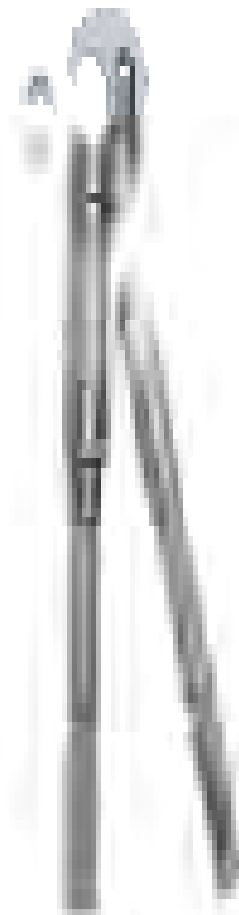
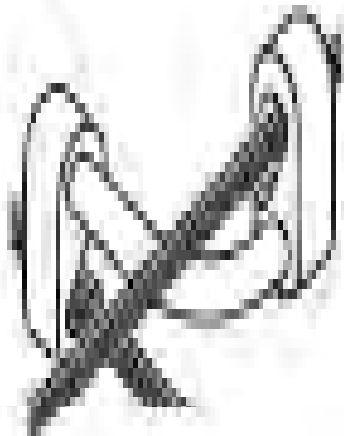
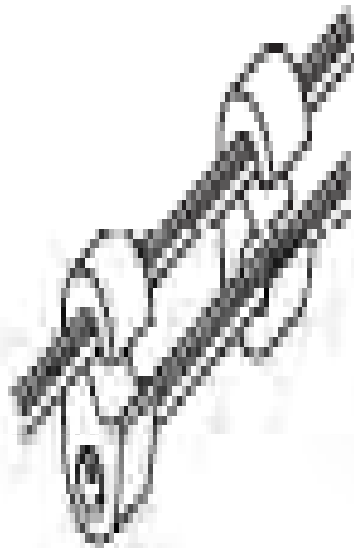
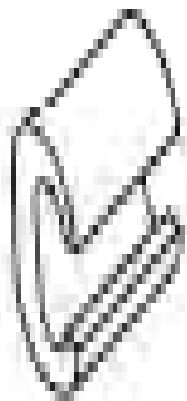


The radius of any bend shall not be less than 203 mm (8 in.)



The angle of any bend shall not be less than 90 degrees.

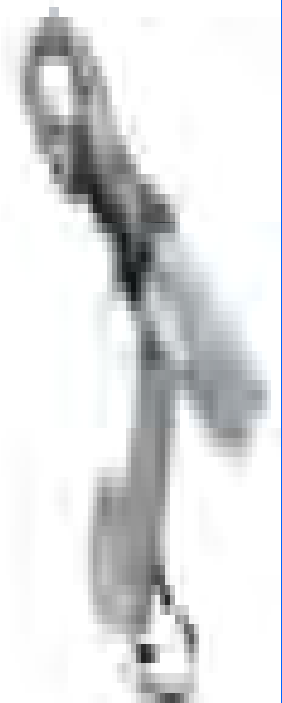
**Examples from HARGER Lightning Protection
Grounding Equipment Catalog**



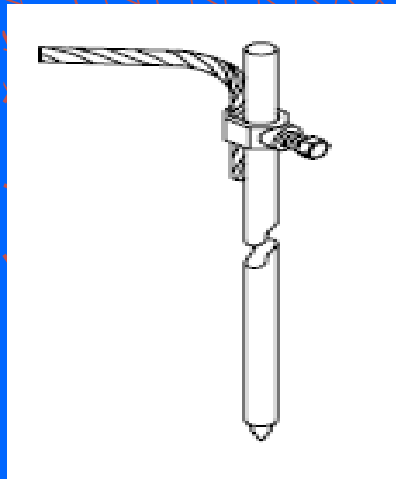
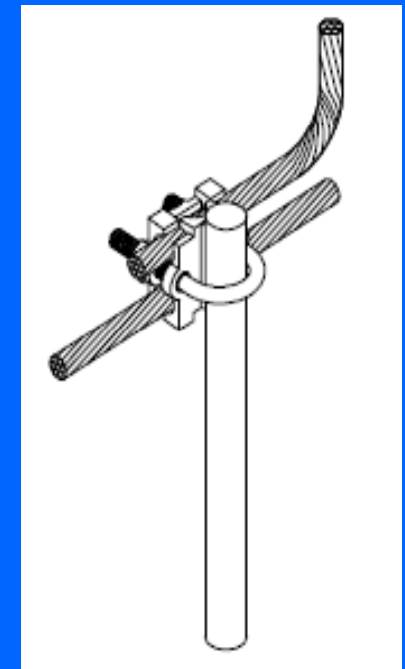
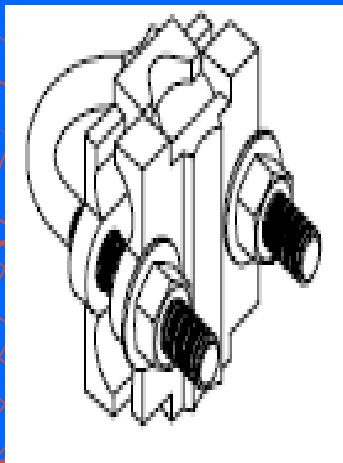
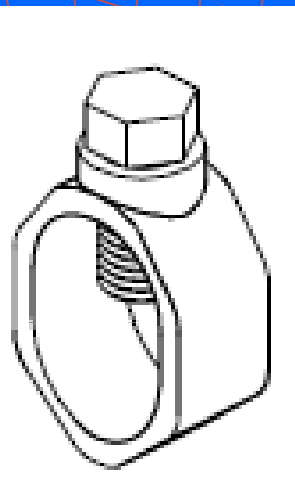
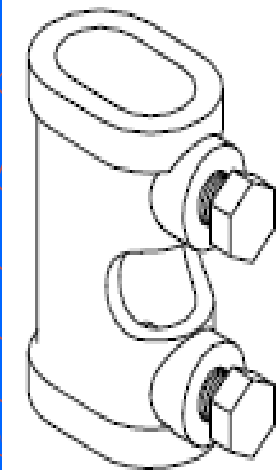
MECHANICAL



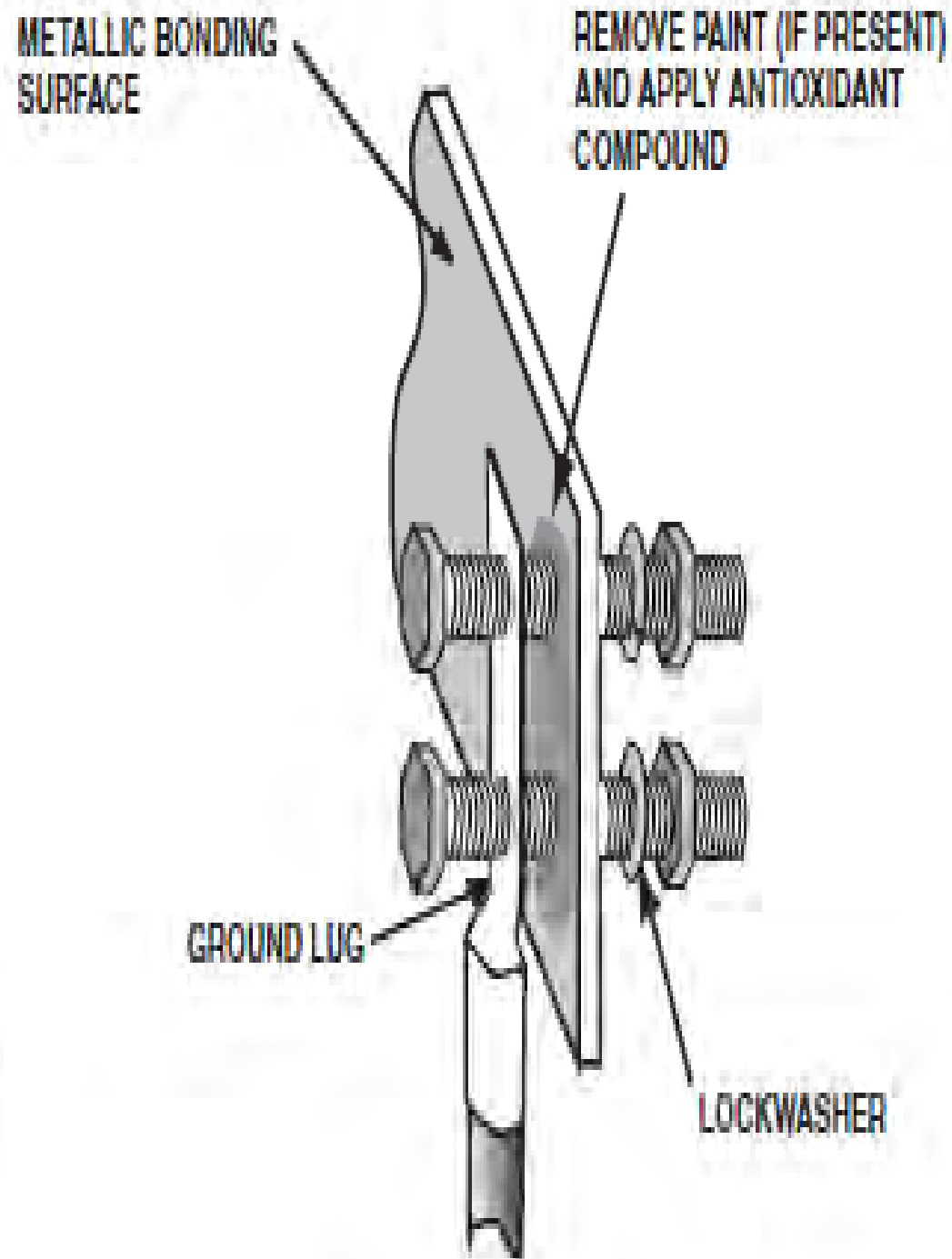
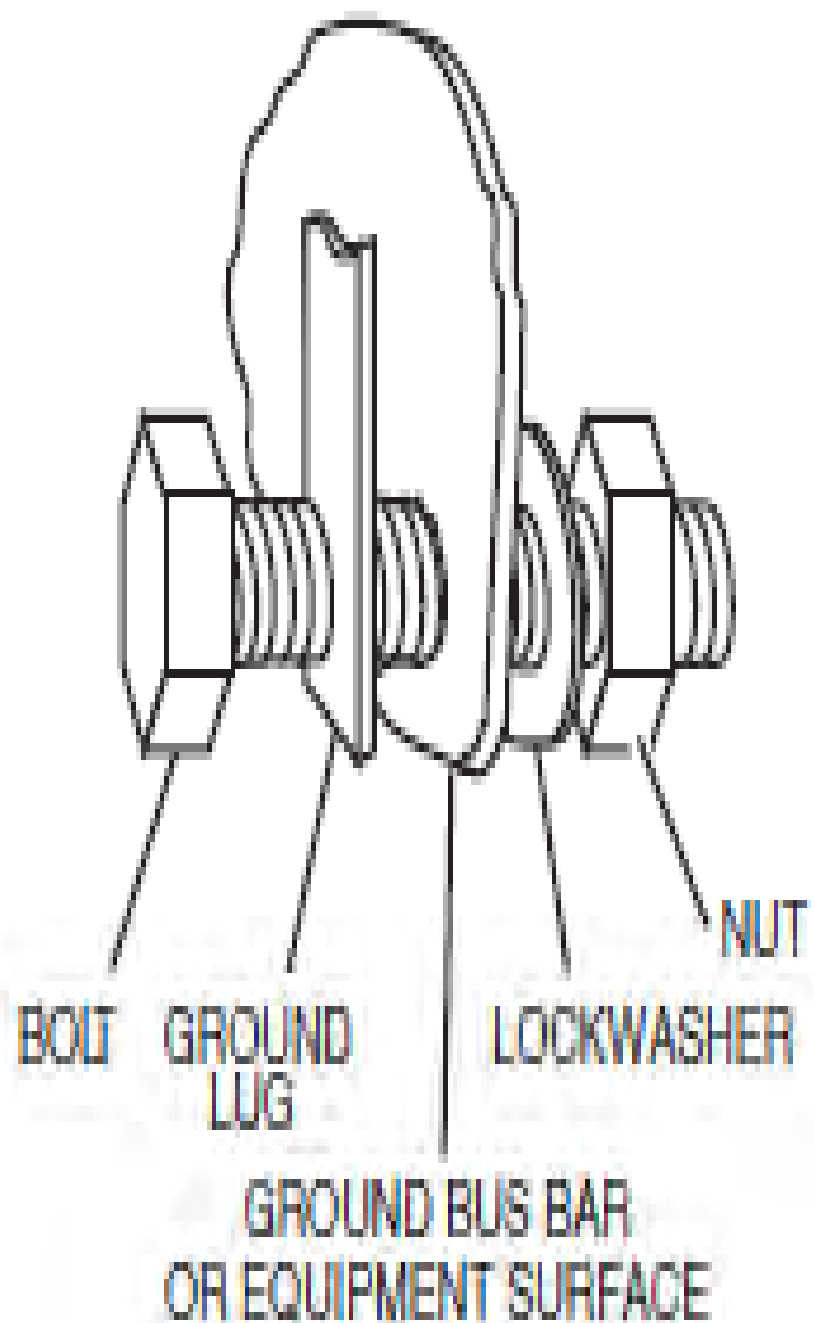
HYDRAULIC



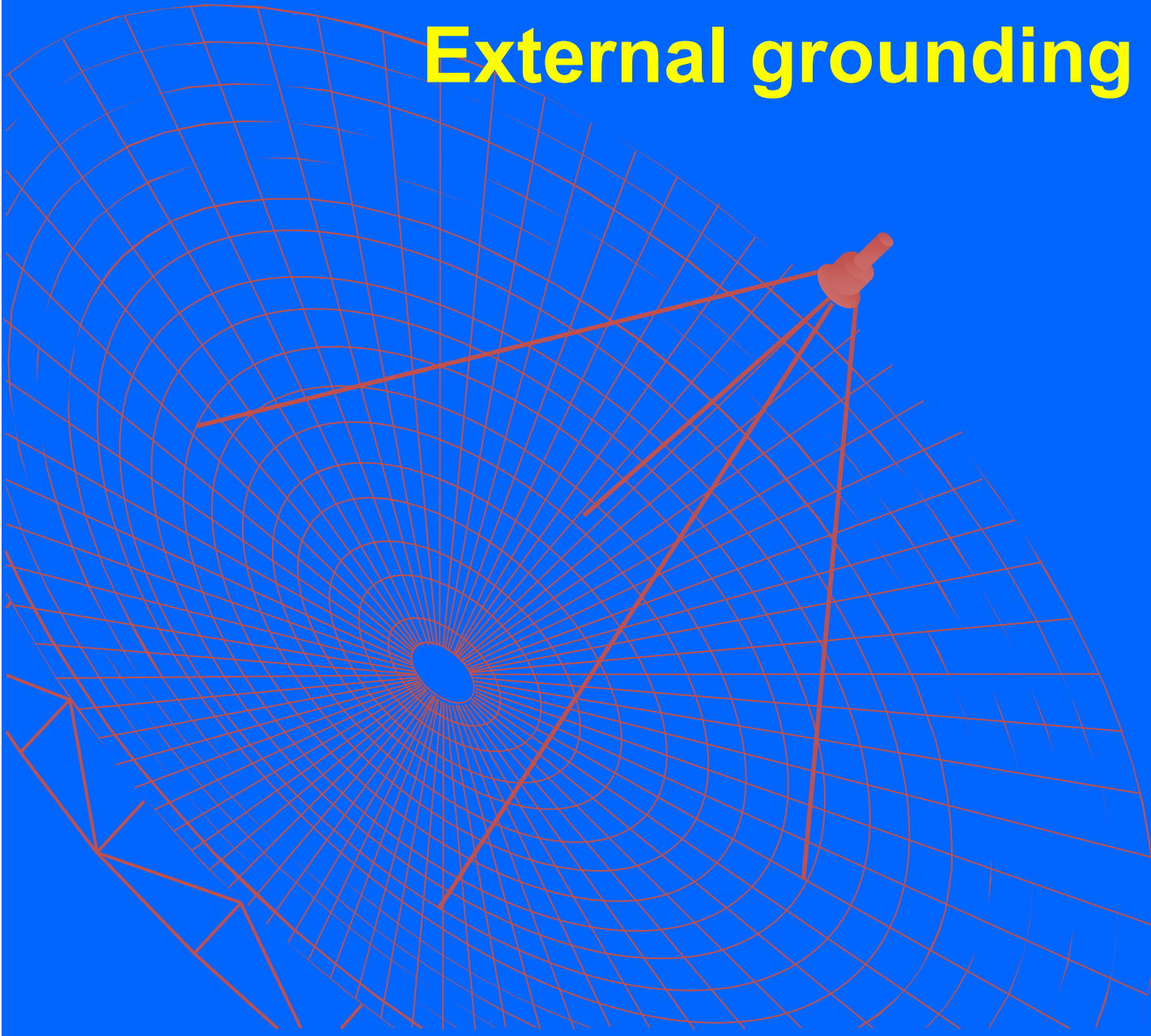
BATTERY-POWERED



**Examples from HARGER Lightning Protection
Grounding Equipment Catalog**



External grounding



Reduce metal corrosion in soil type

Gravelly soils --least aggressive

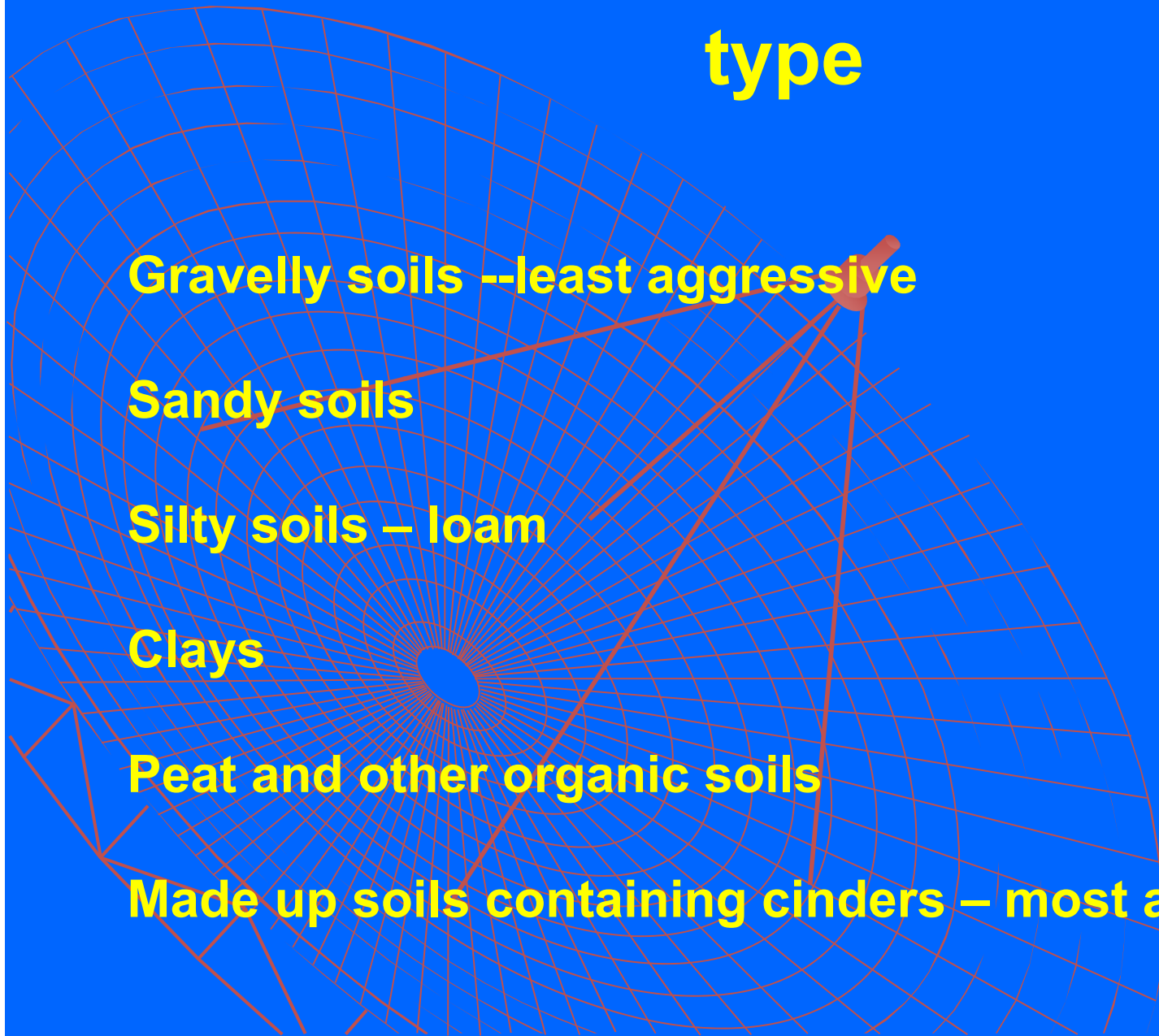
Sandy soils

Silty soils – loam

Clays

Peat and other organic soils

Made up soils containing cinders – most aggressive



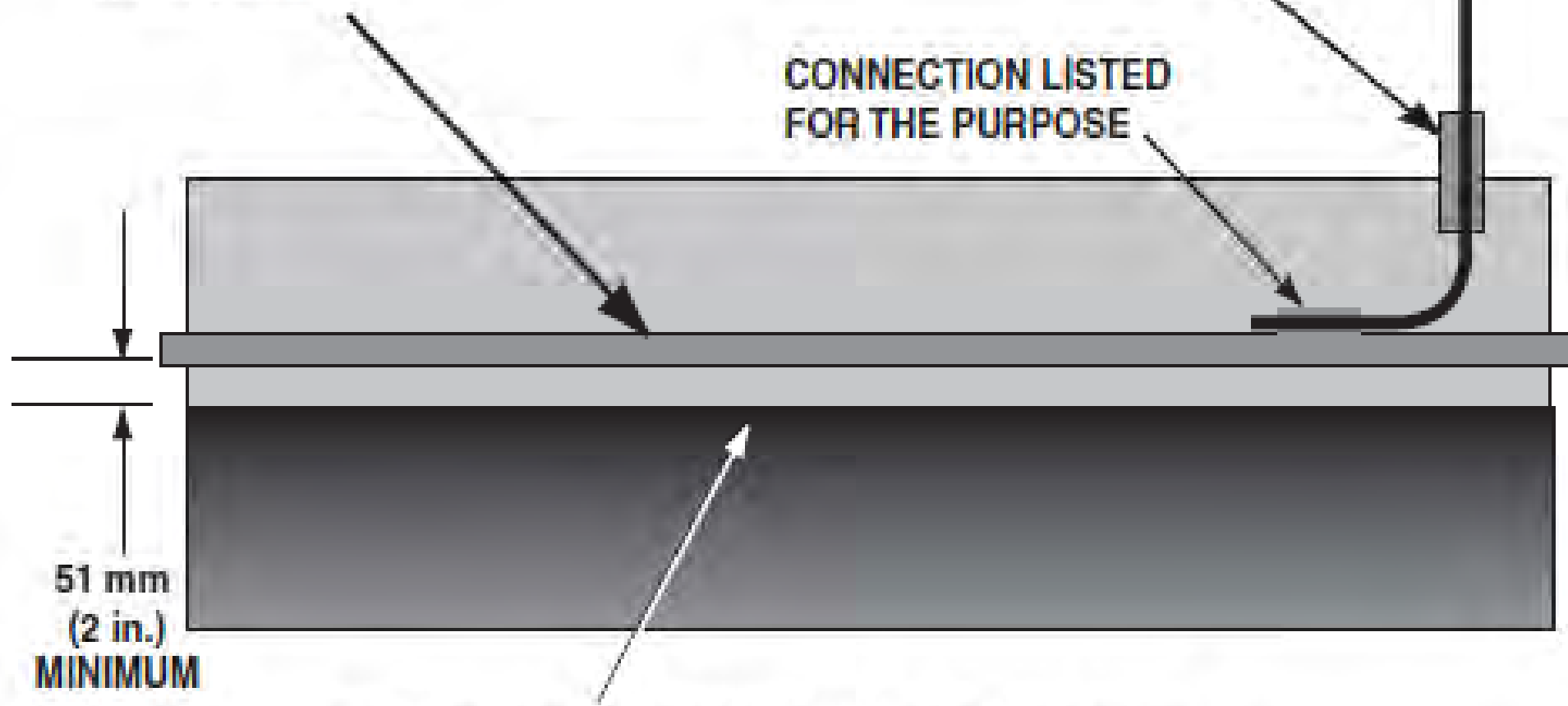


25 mm² CSA (#4 AWG) OR
COARSER BARE COPPER
CONDUCTOR OR STEEL
REINFORCING BAR OR ROD, NOT
LESS THAN 12.7 mm (0.5 in.)
DIAMETER AND AT LEAST 6.1 m
(20 ft) LONG

GROUNDING ELECTRODE
CONDUCTOR

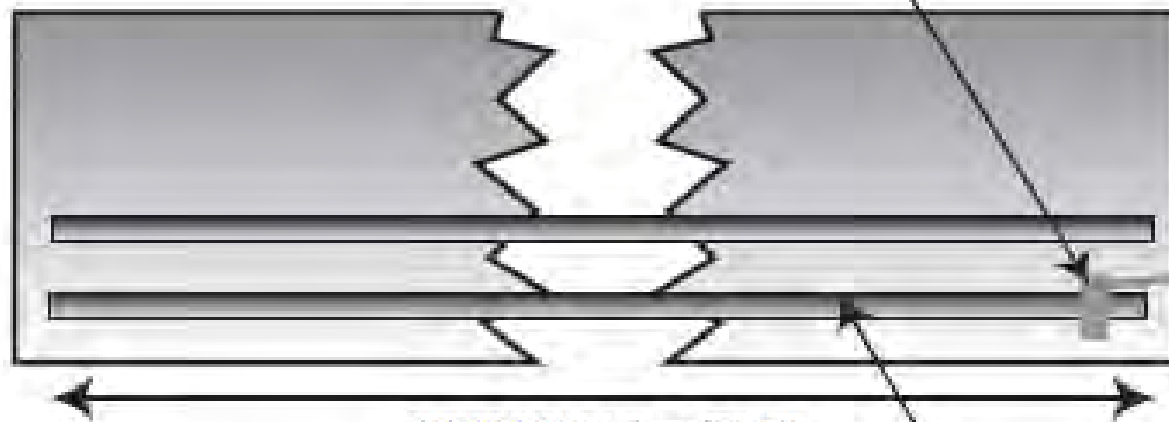
NONMETALLIC
PROTECTIVE SLEEVE

CONNECTION LISTED
FOR THE PURPOSE



FOUNDATION IN DIRECT CONTACT WITH EARTH

CLAMP SUITABLE FOR ENCASEMENT
OR EXOTHERMIC WELD



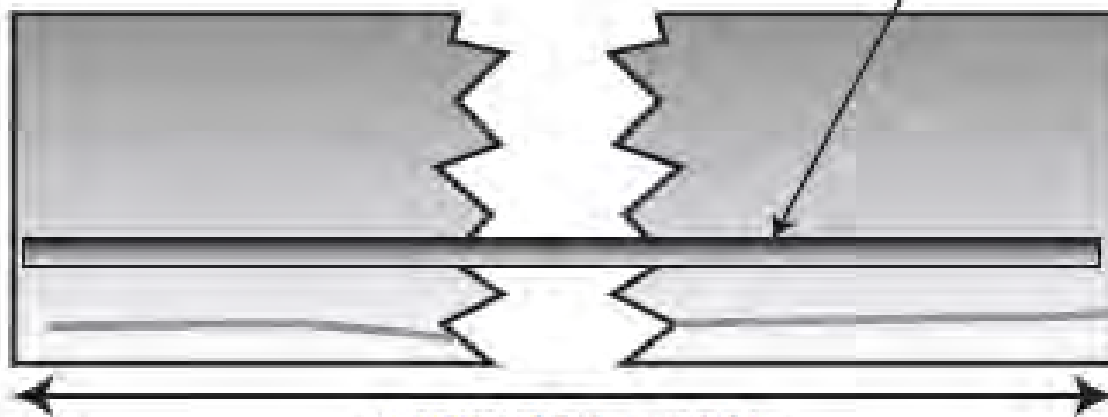
MINIMUM 6.1 m (20 ft)

SIDE VIEW

12.7 mm (0.5 in.) REBAR
(TYPICAL)



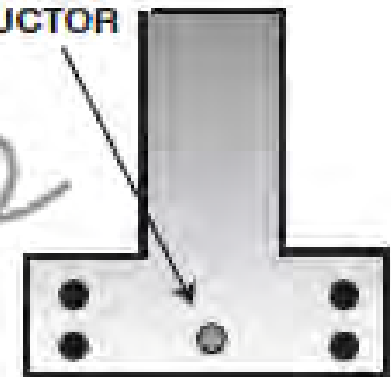
END VIEW



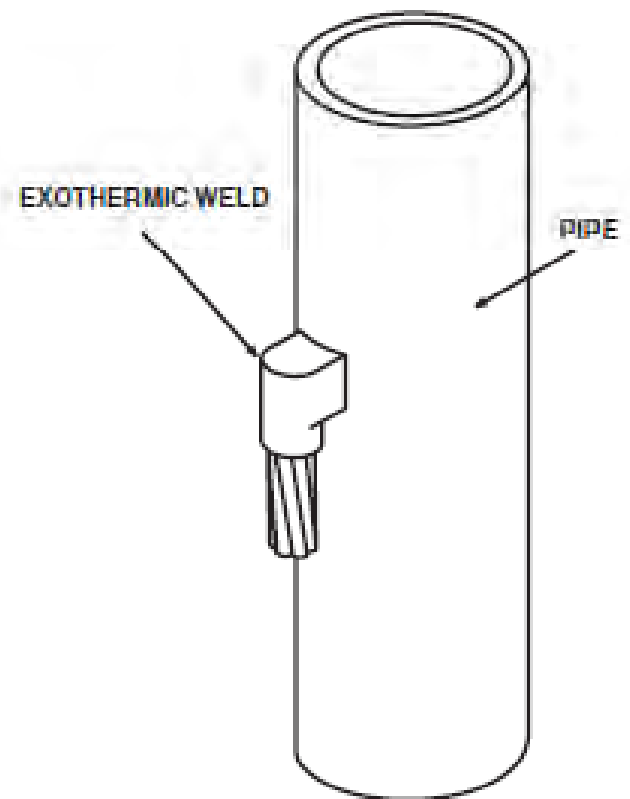
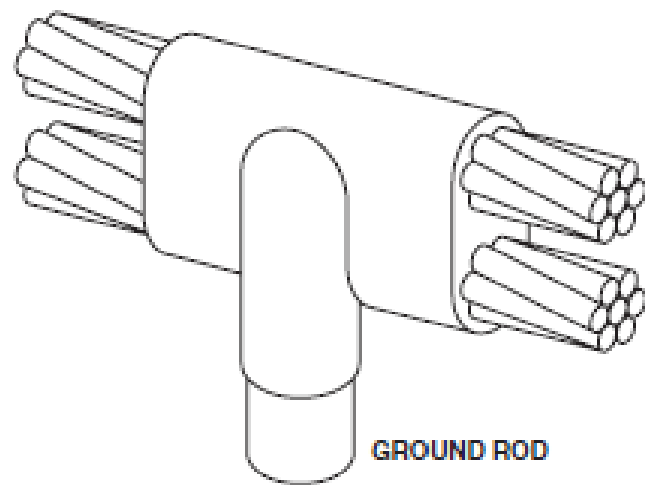
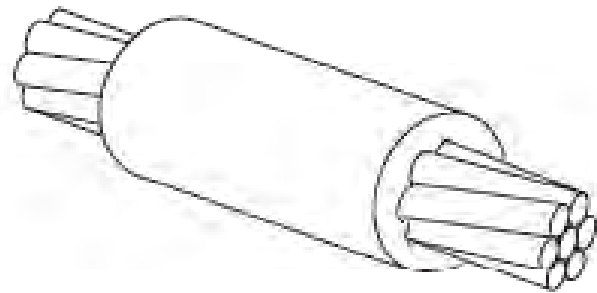
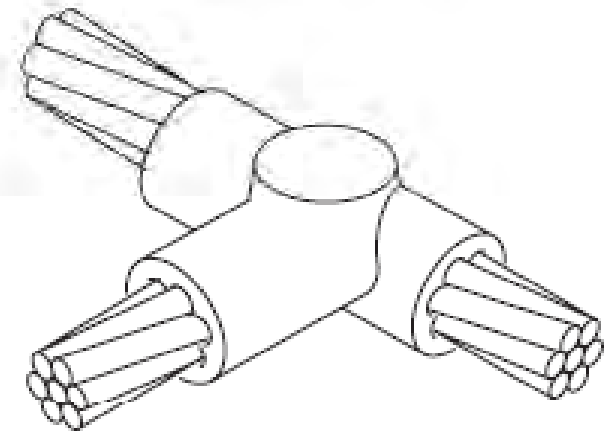
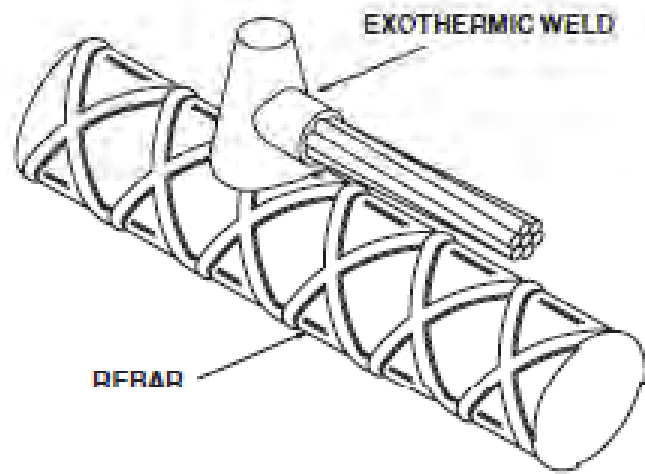
MINIMUM 6.1 m (20 ft)

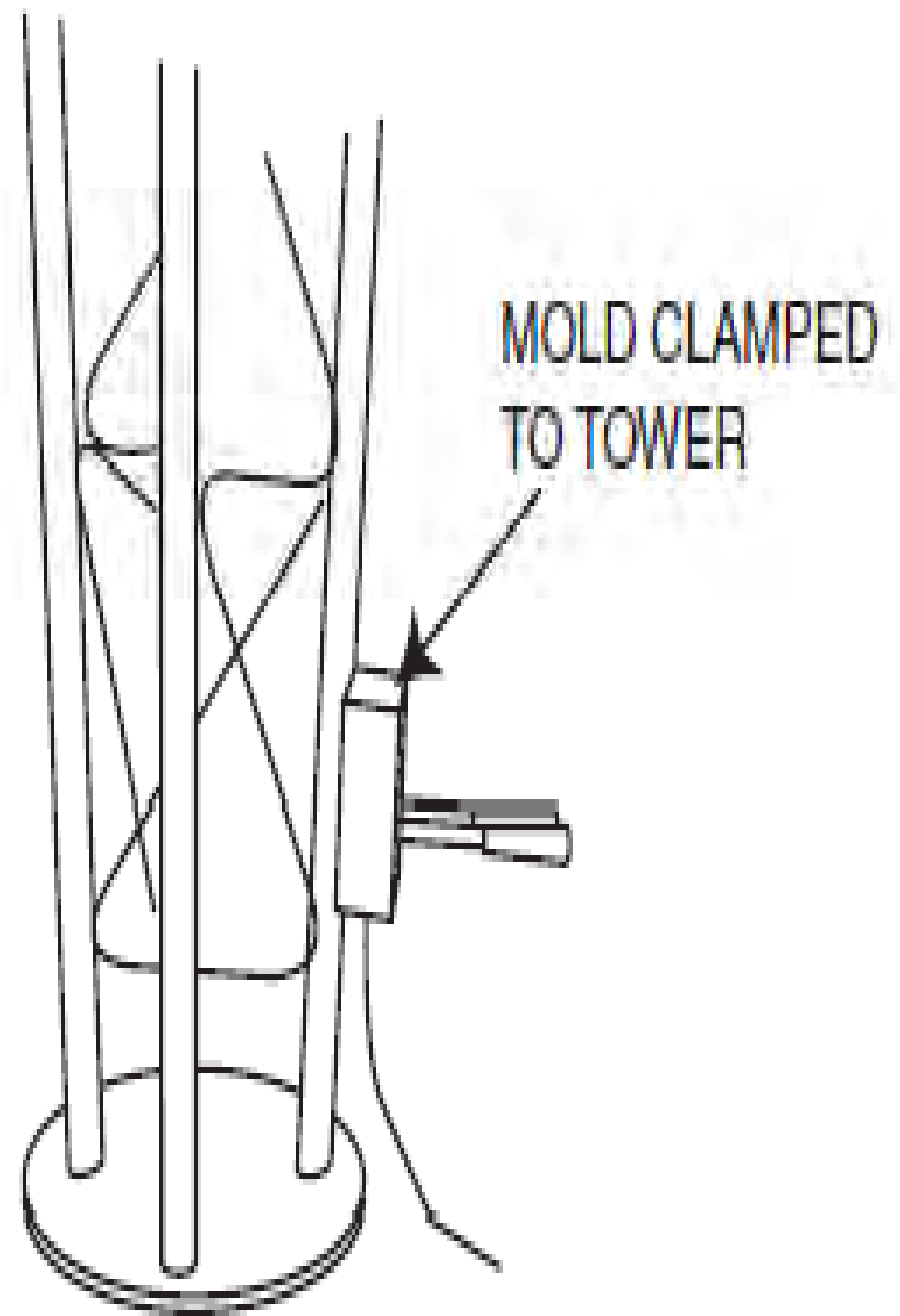
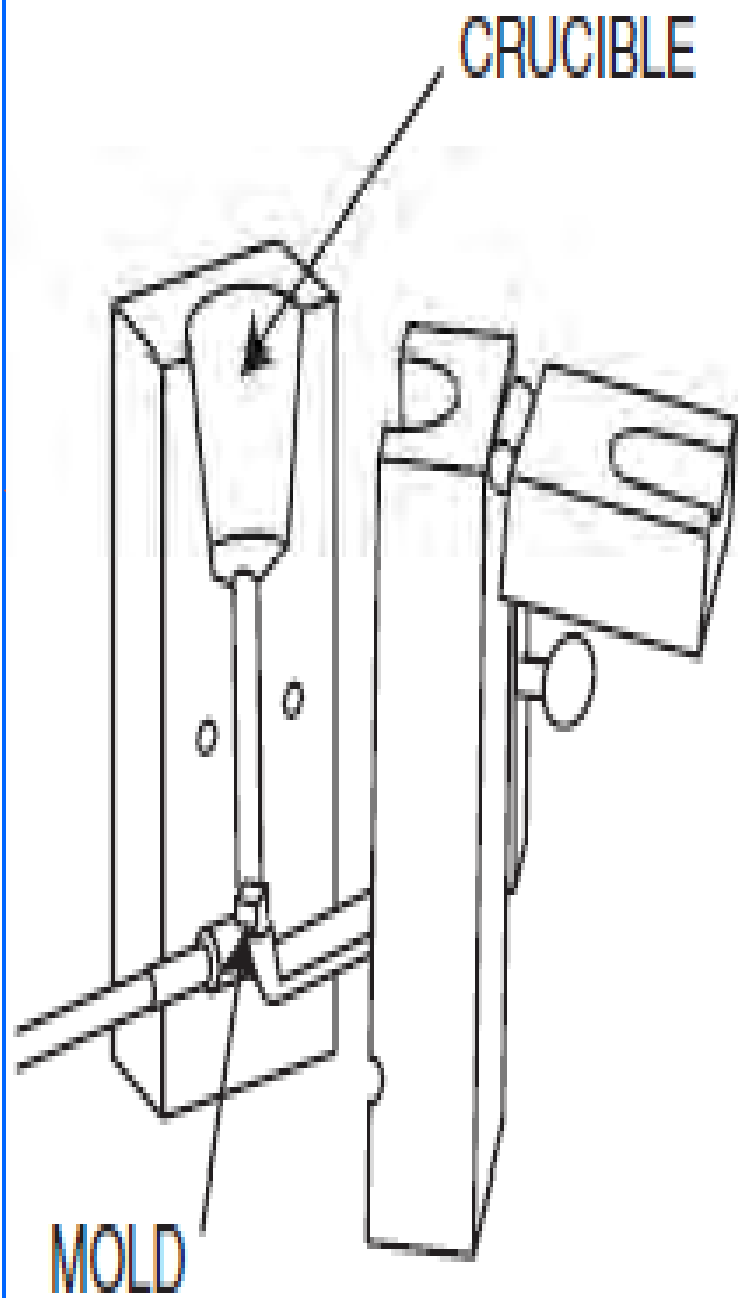
SIDE VIEW

25 mm² csa (#4 AWG)
COPPER CONDUCTOR



END VIEW



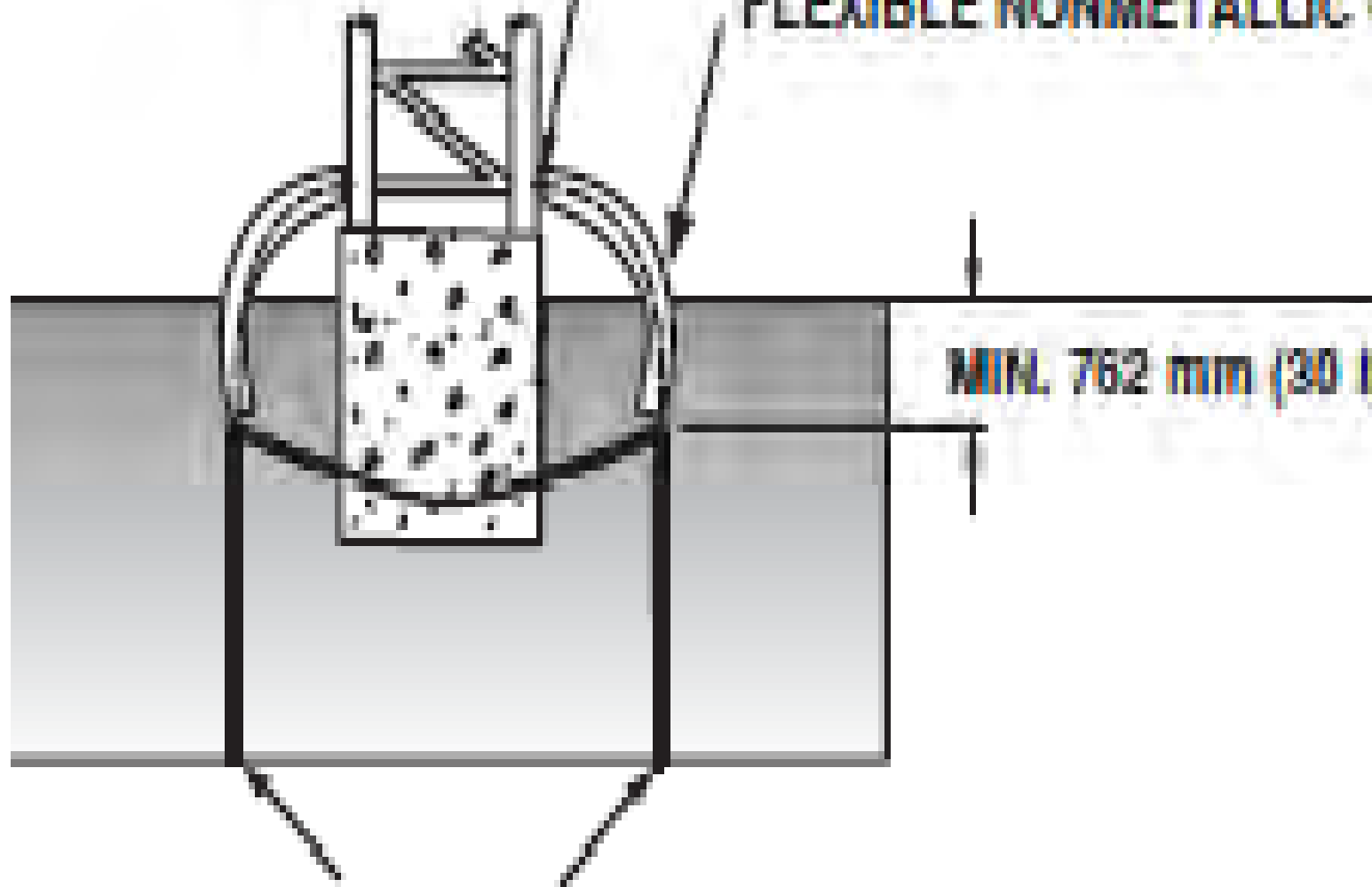


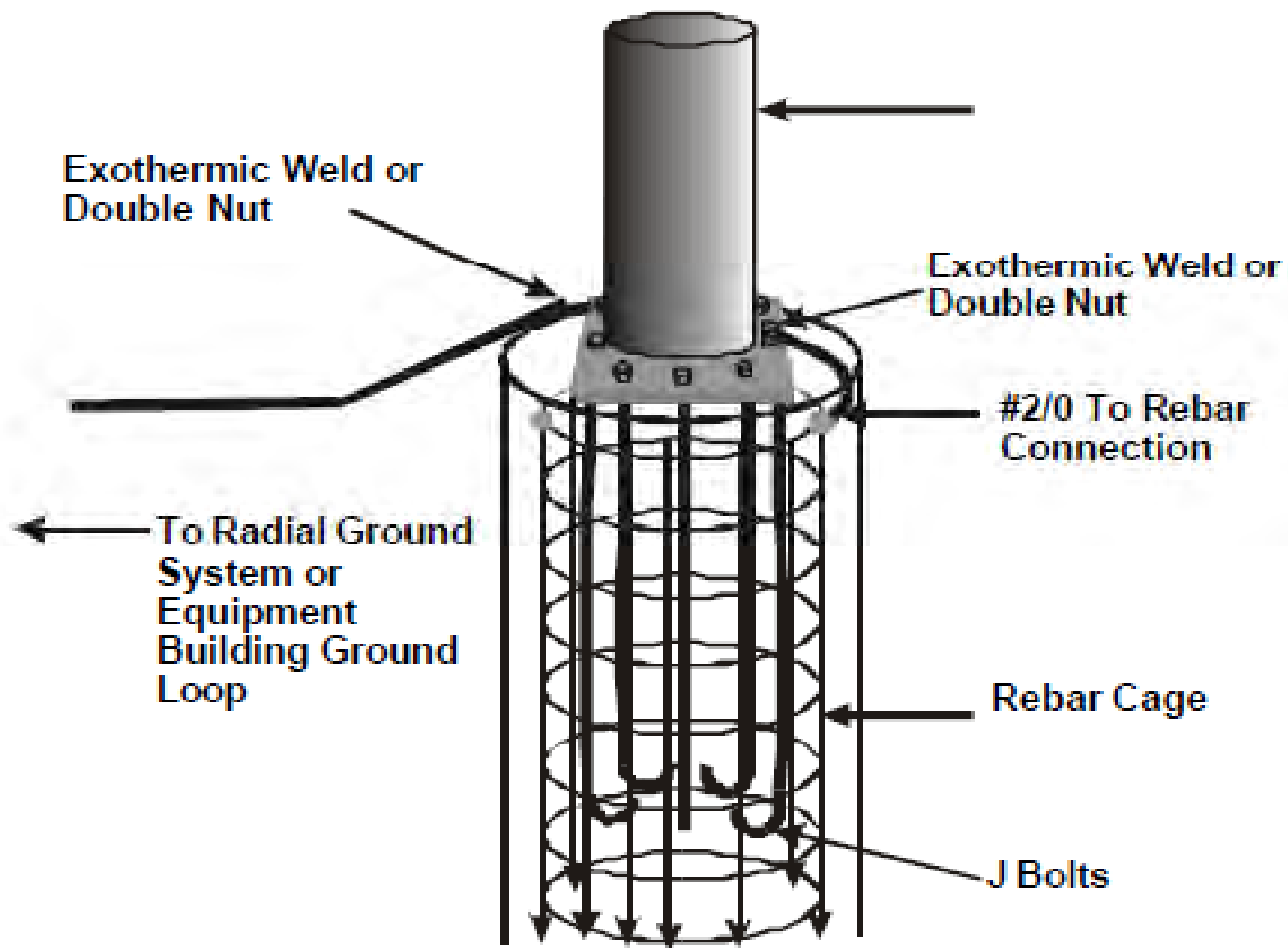
EXOTHERMIC WELD
OR MECHANICAL CLAMP

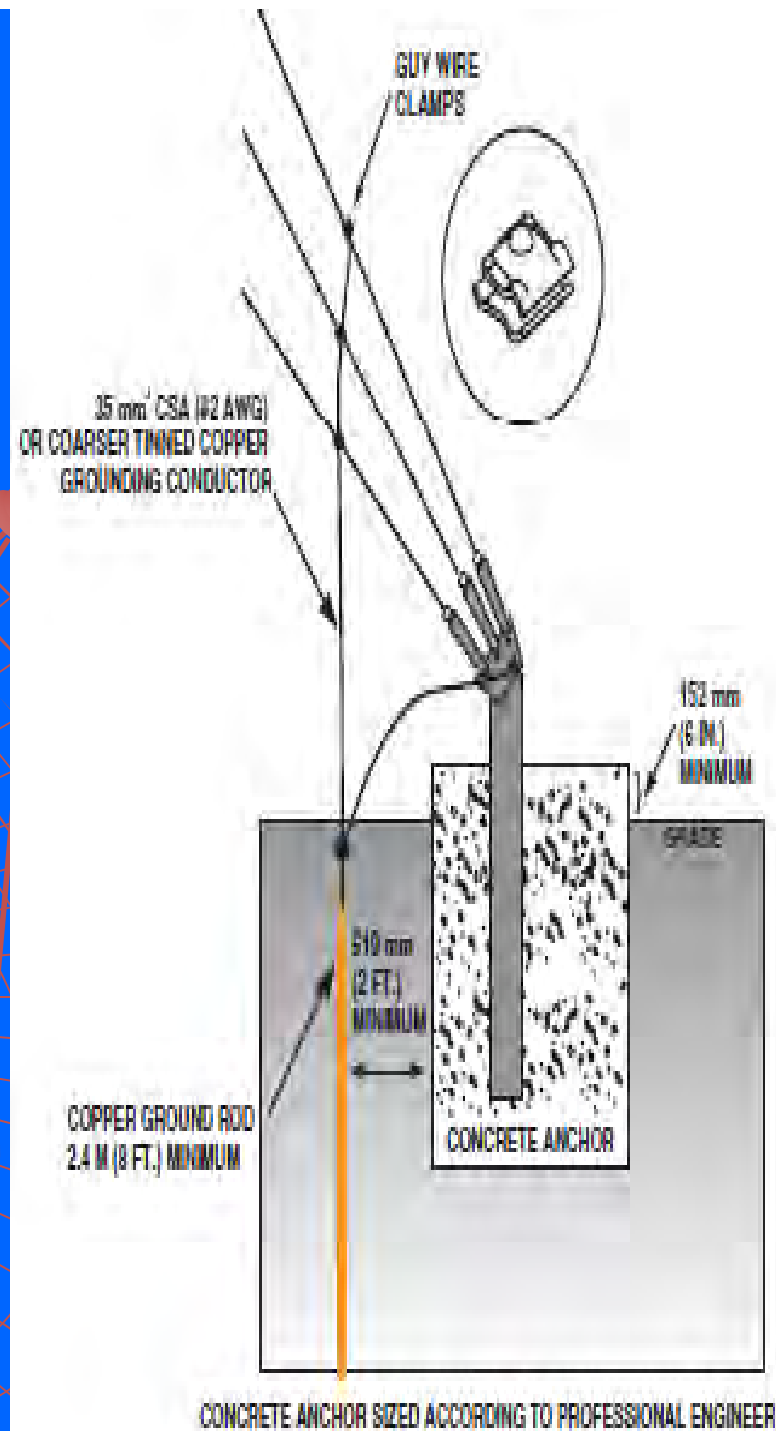
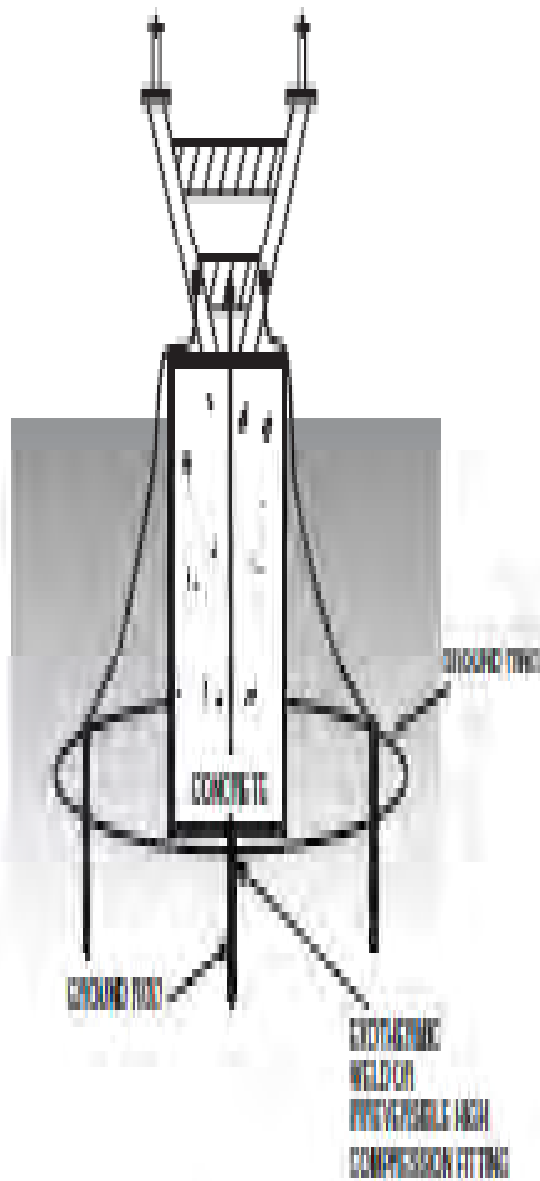
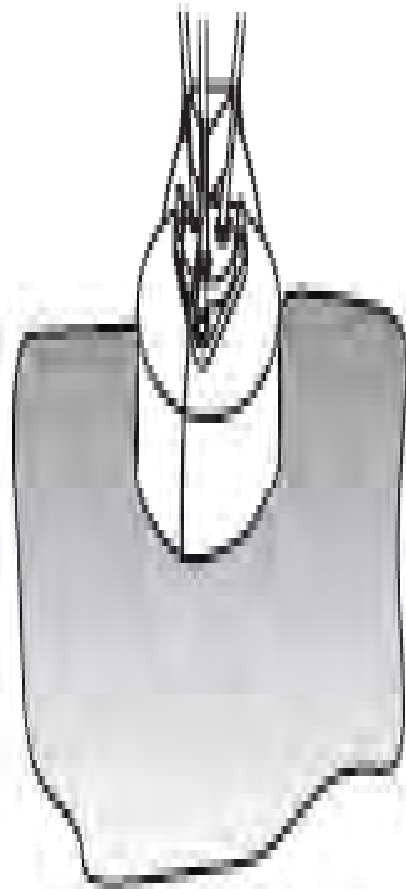
FLEXIBLE NONMETALLIC CONDUIT

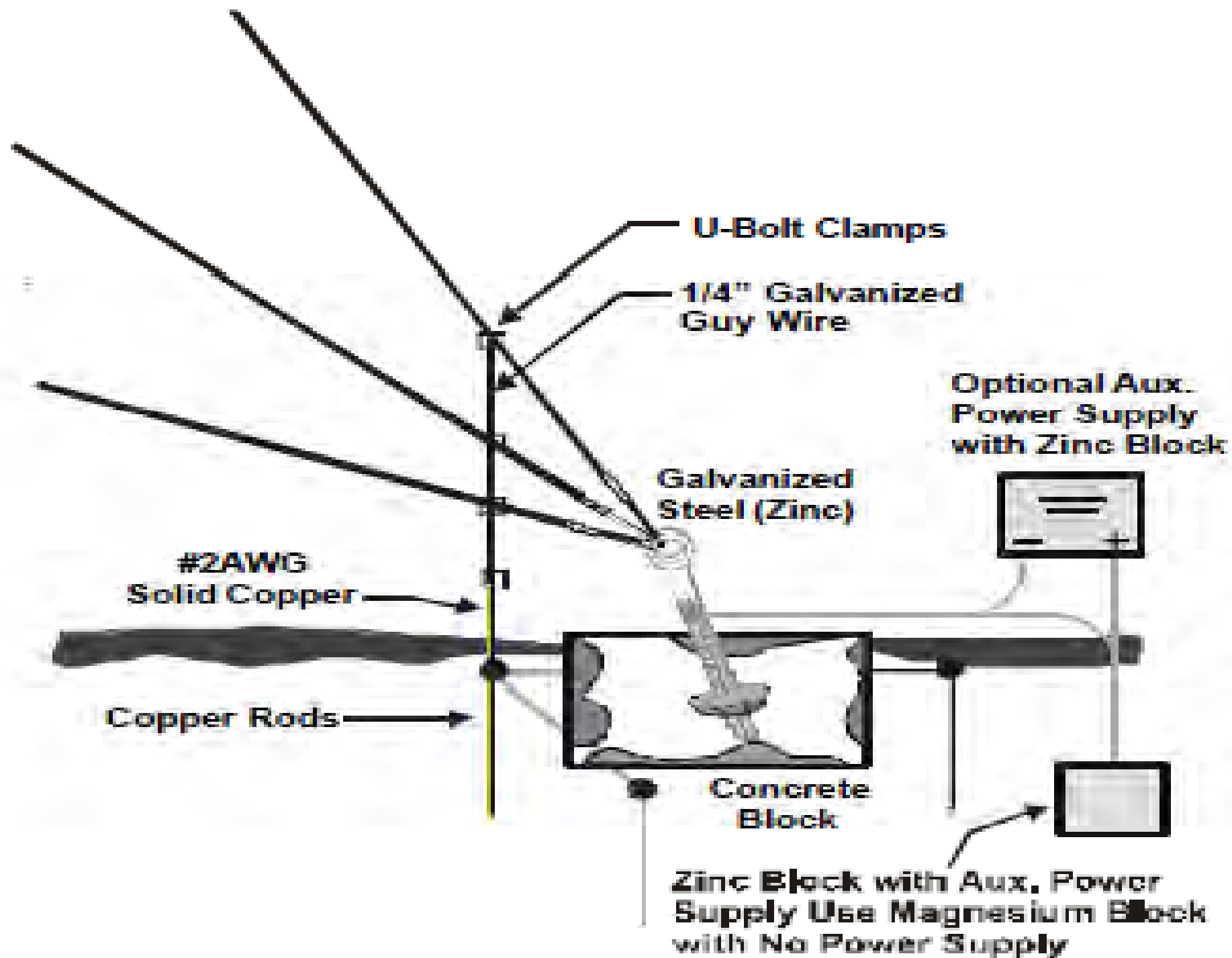
MIN. 762 mm (30 in.)

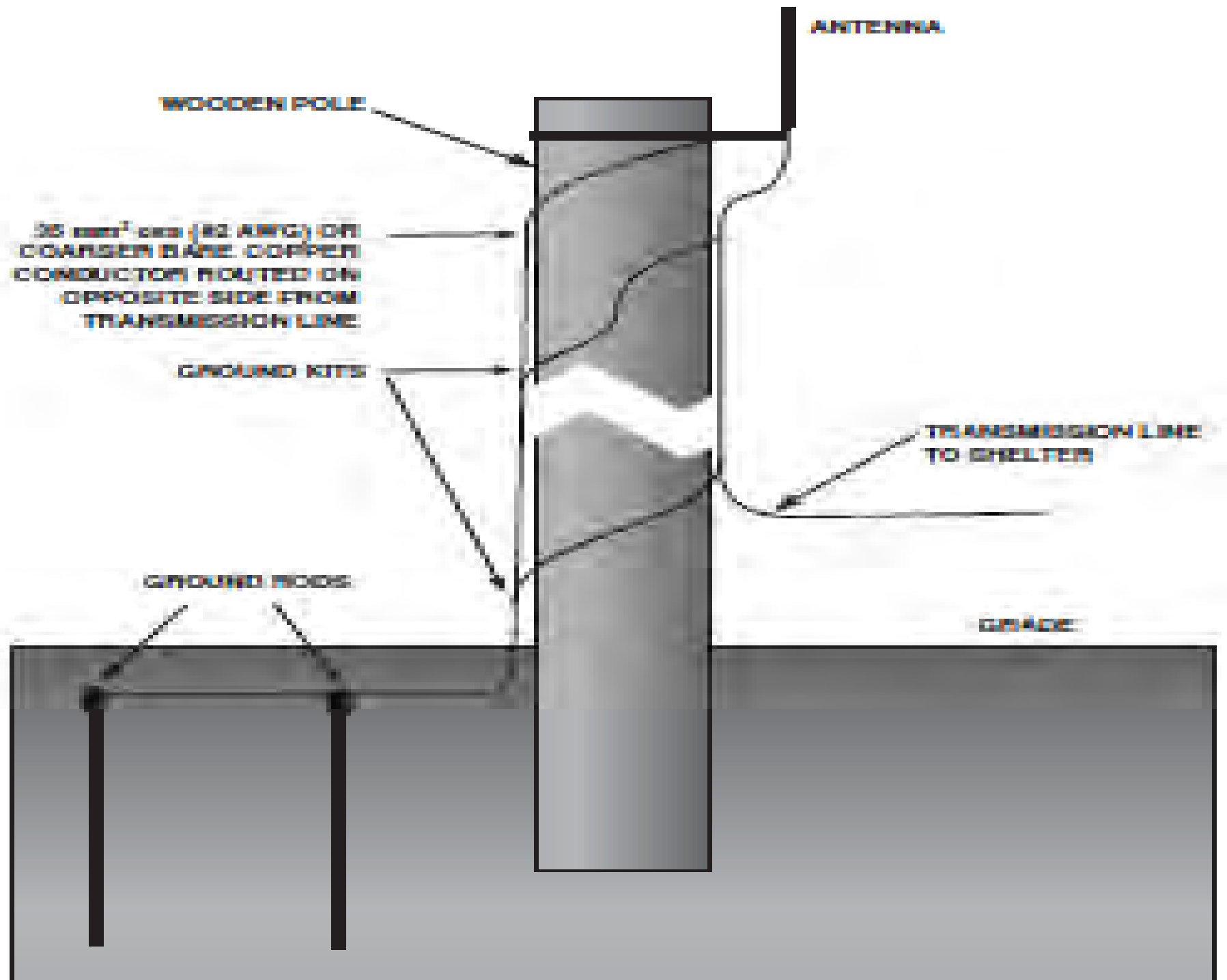
GROUND RODS

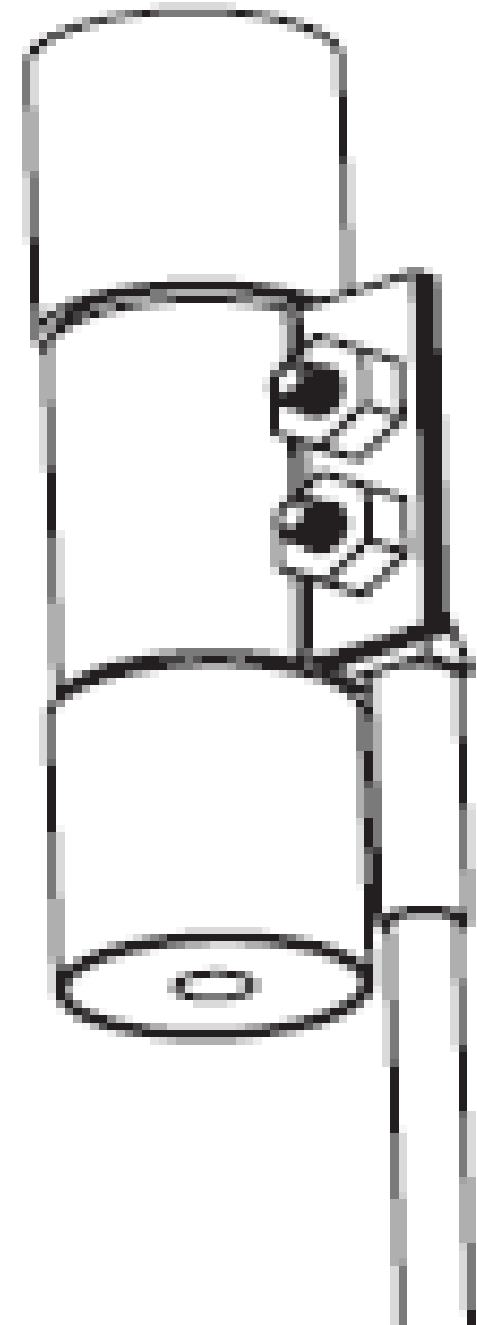
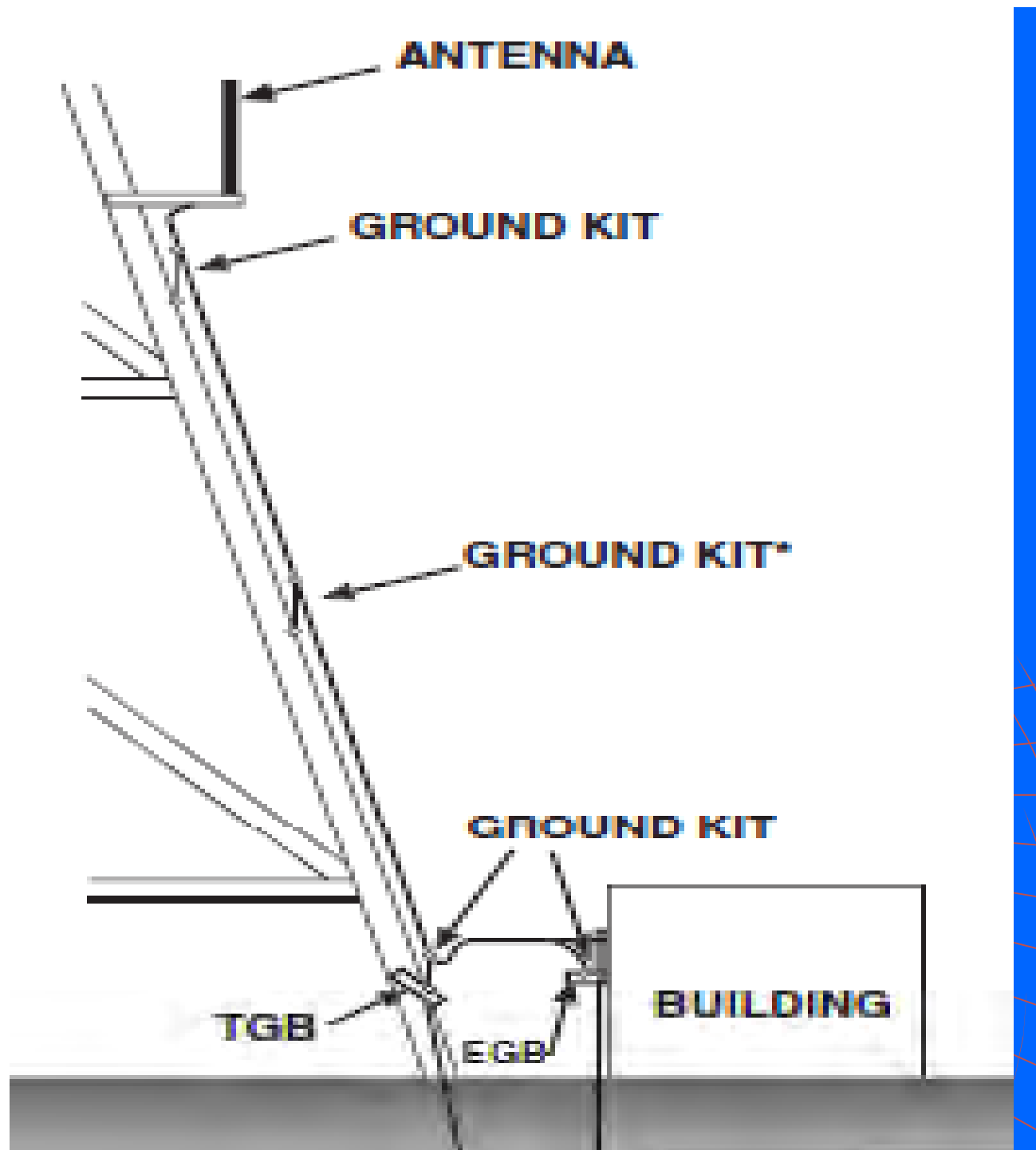


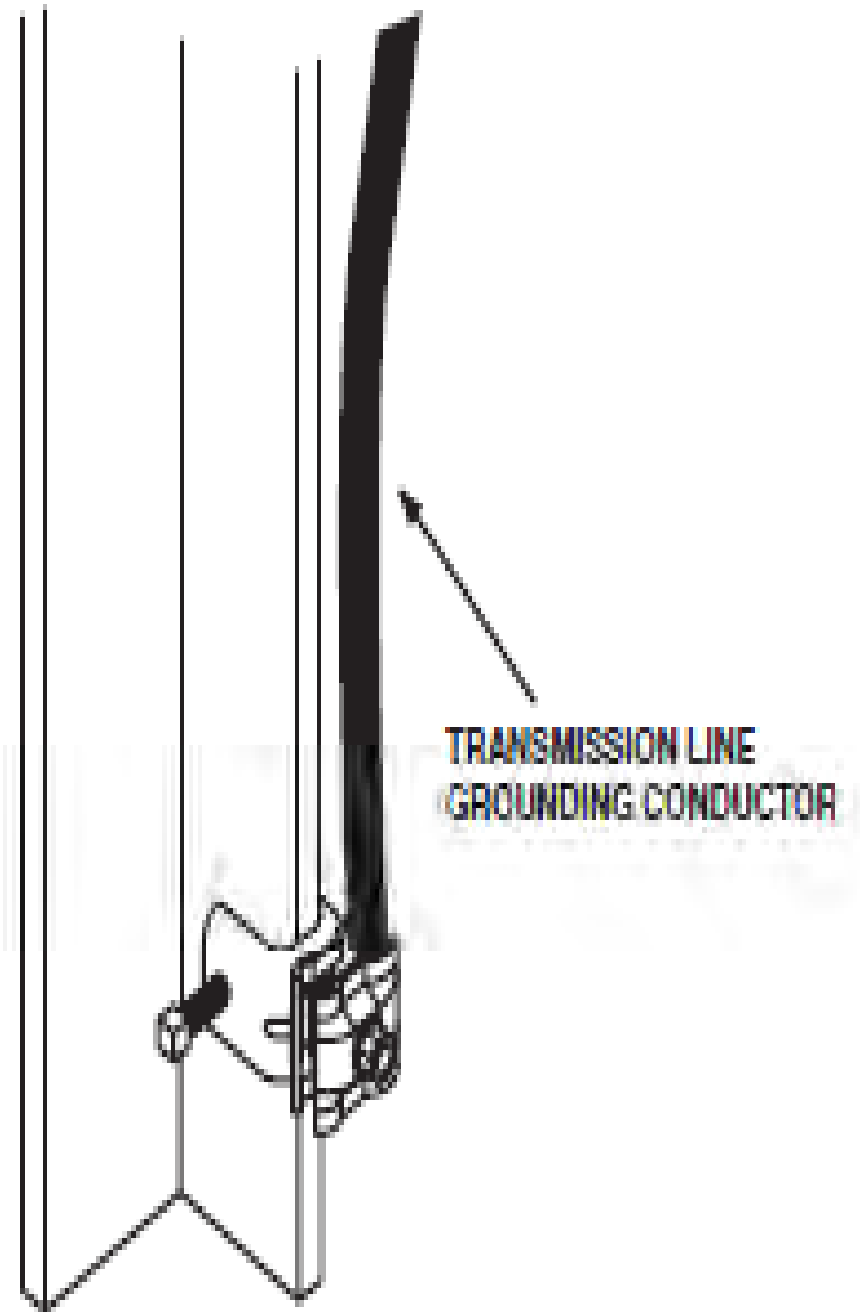
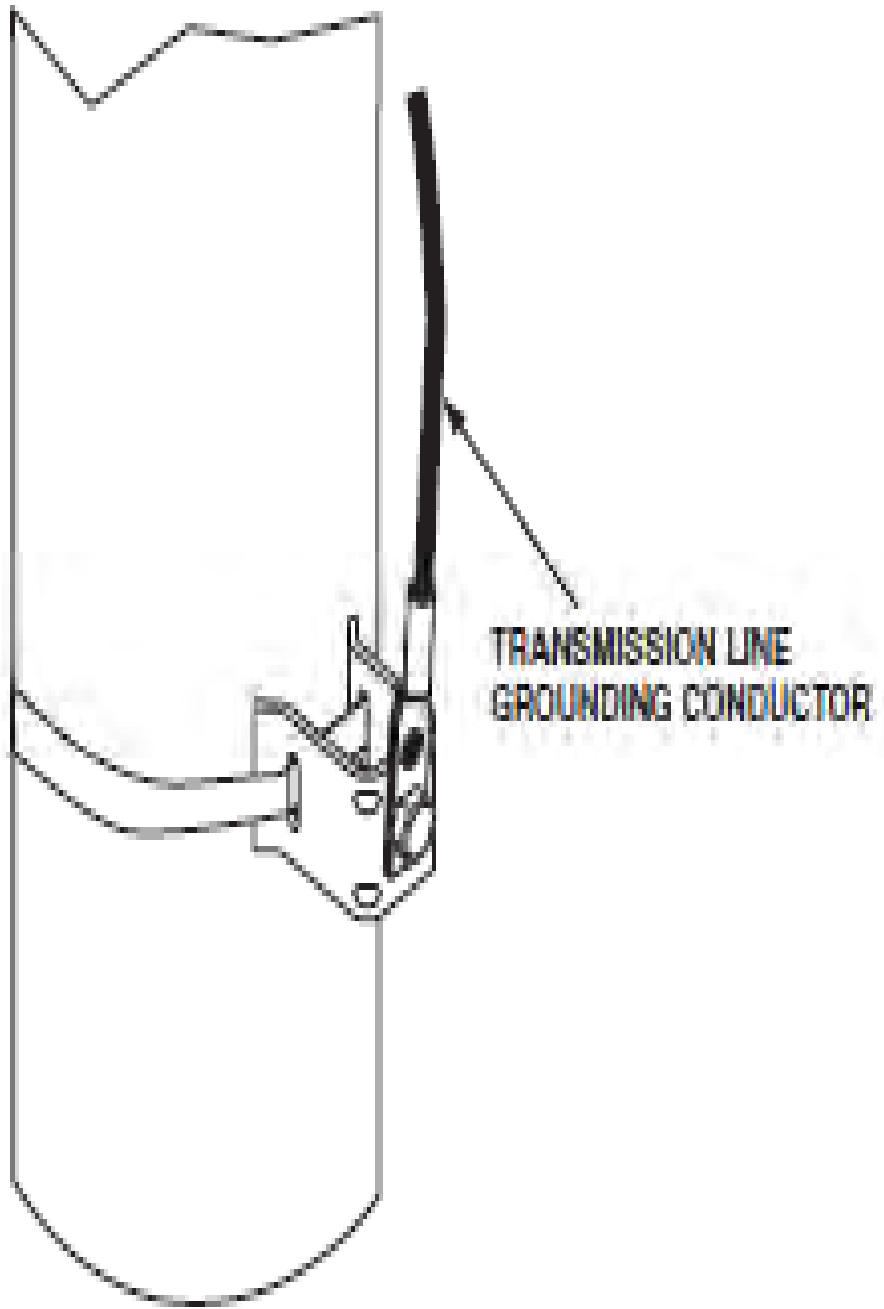


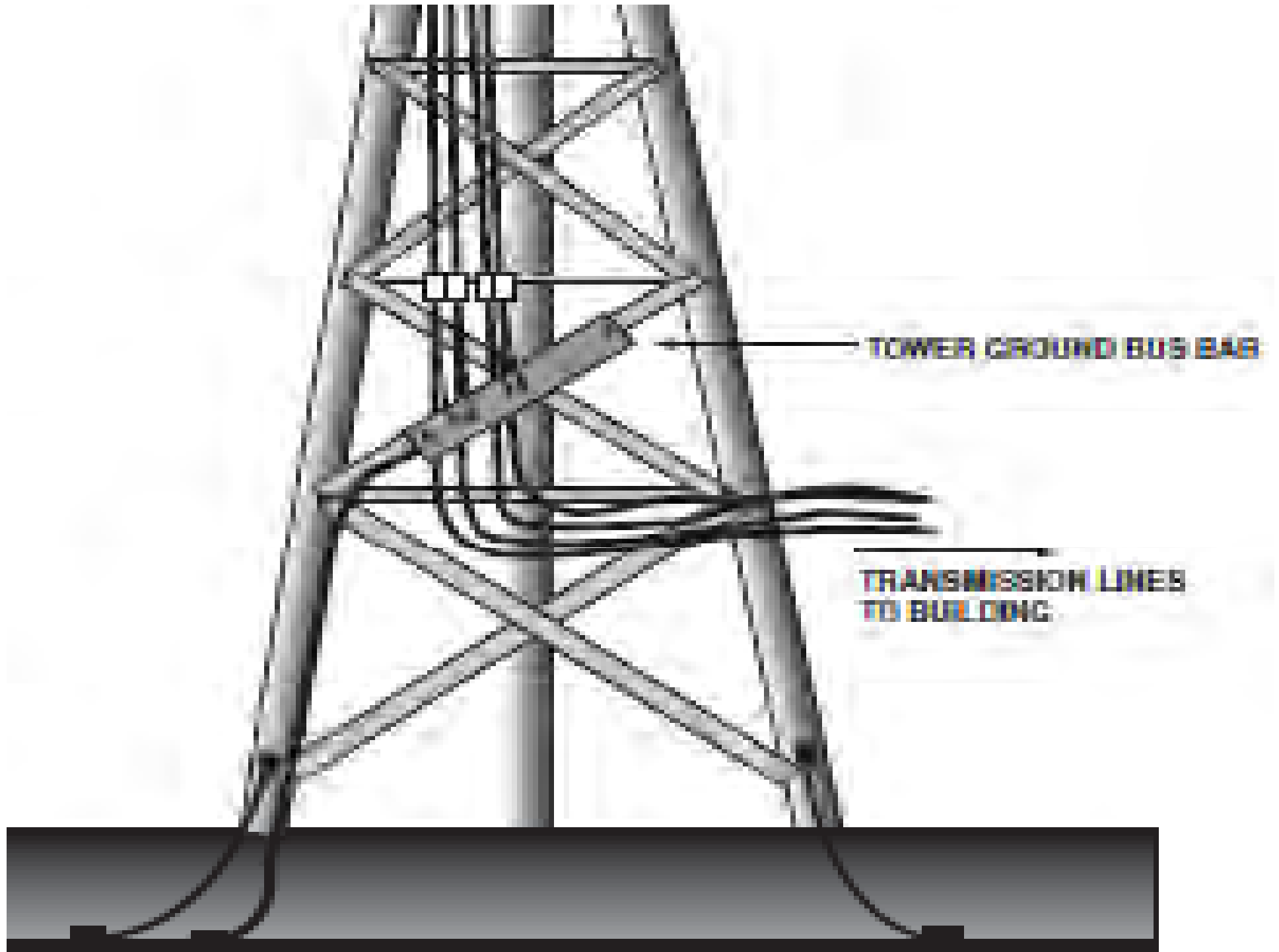


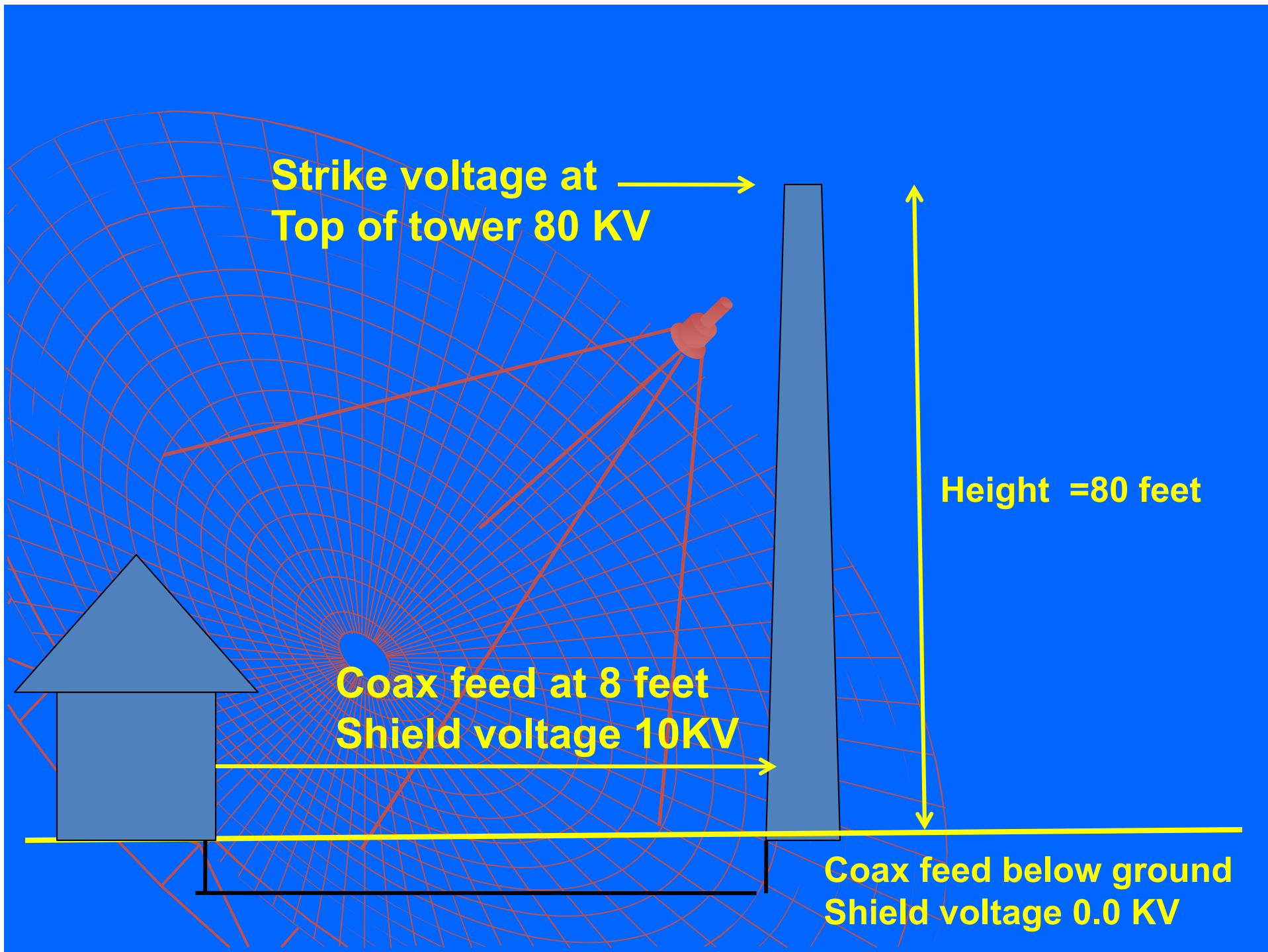




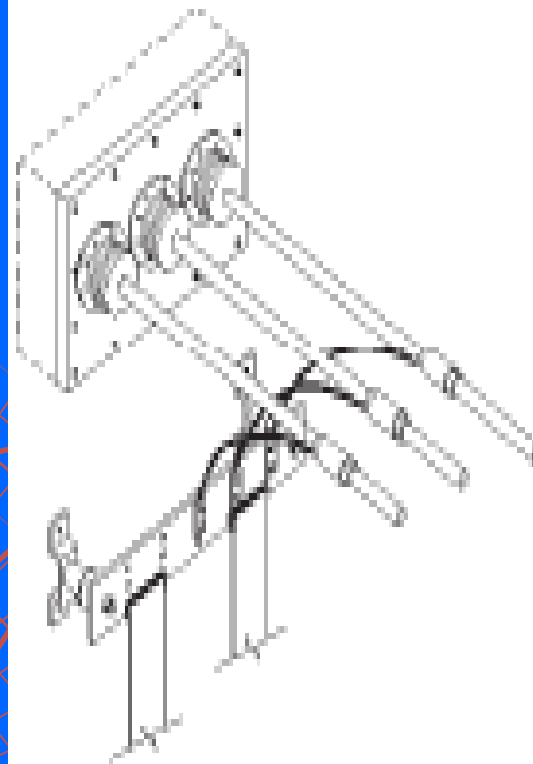
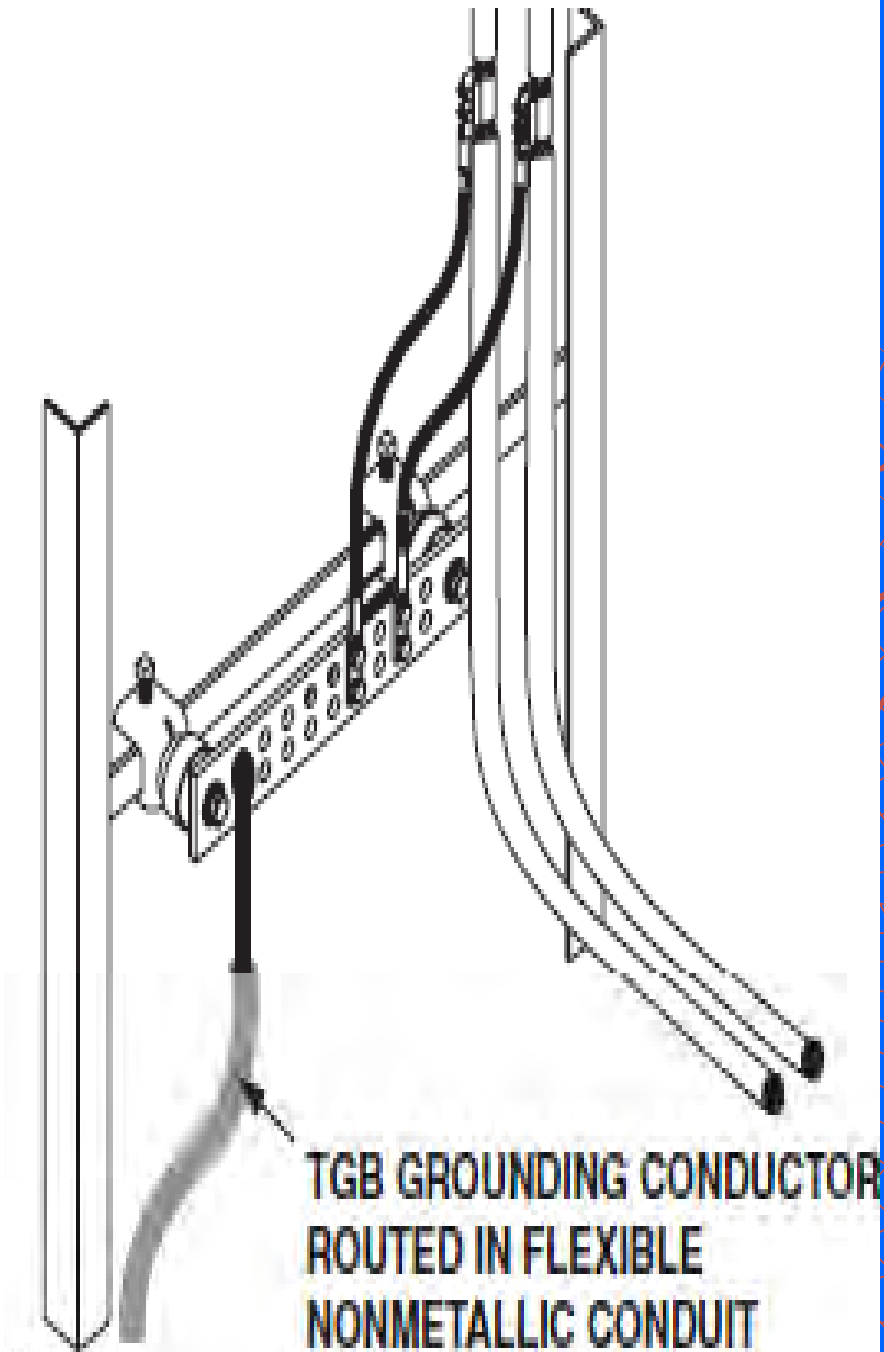




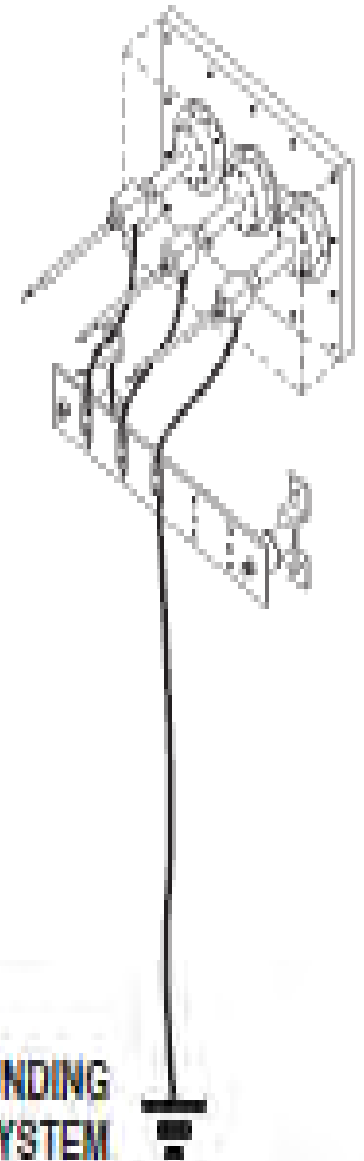




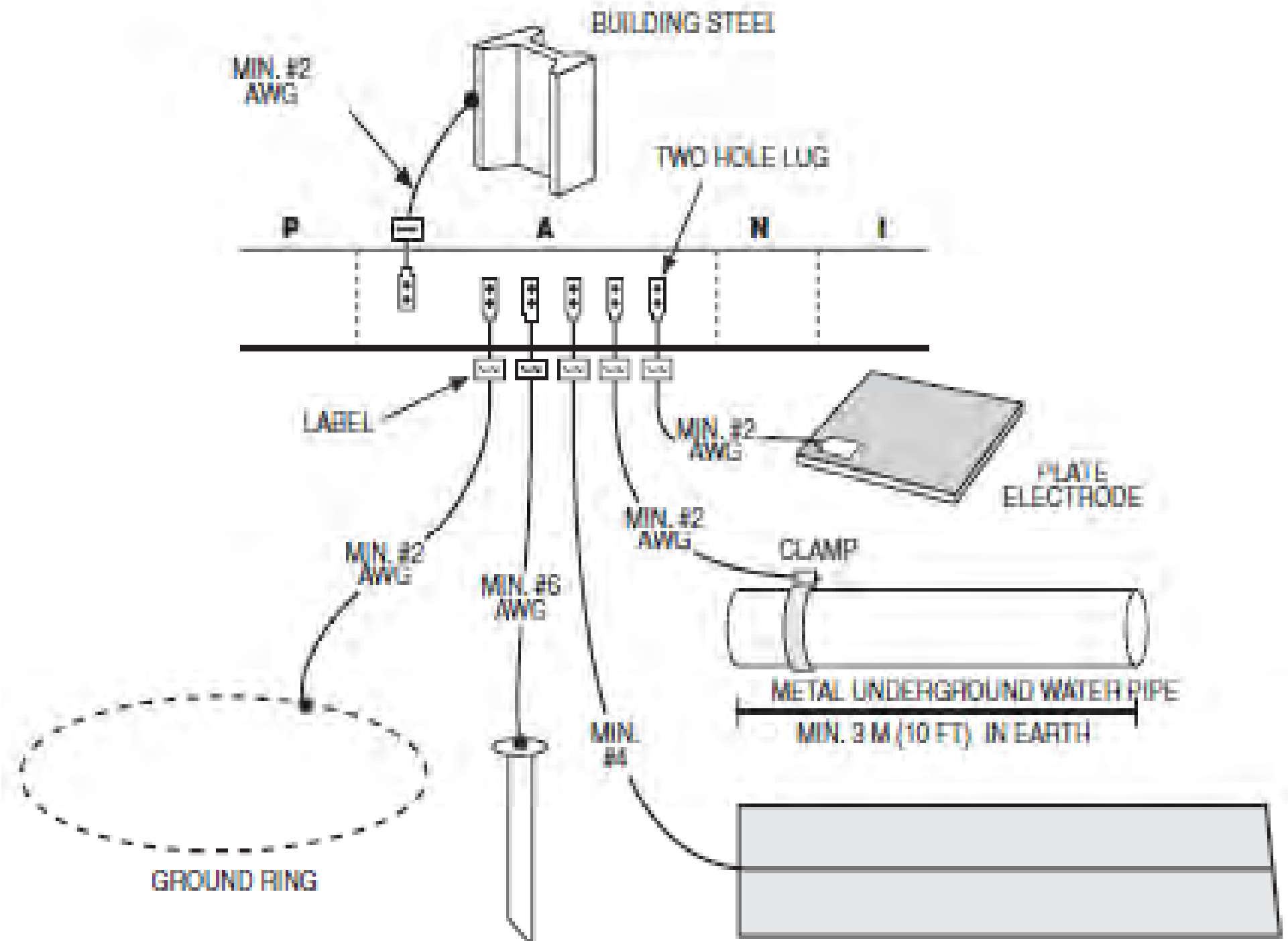




EXTERIOR



INTERIOR



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.

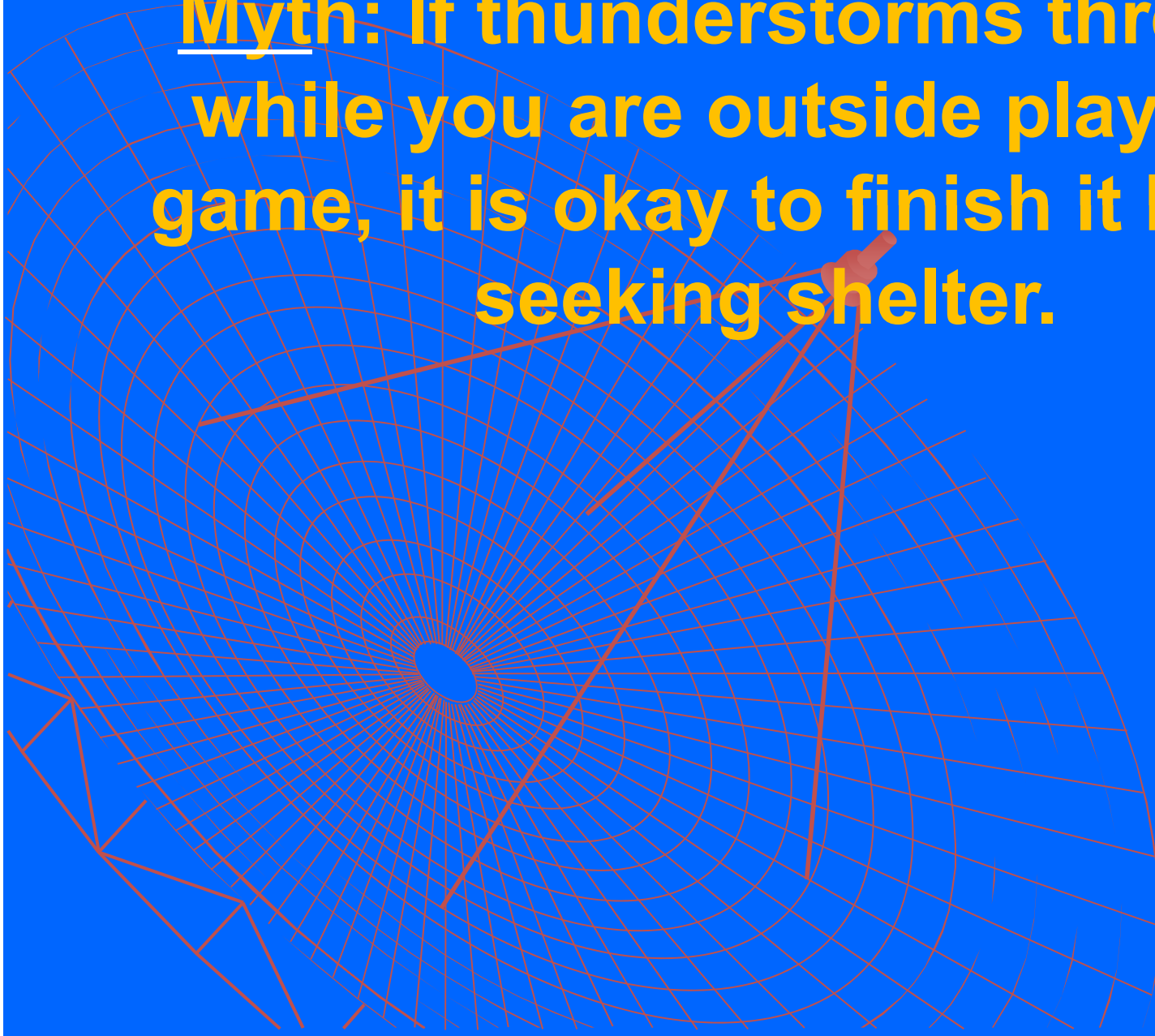


Myths

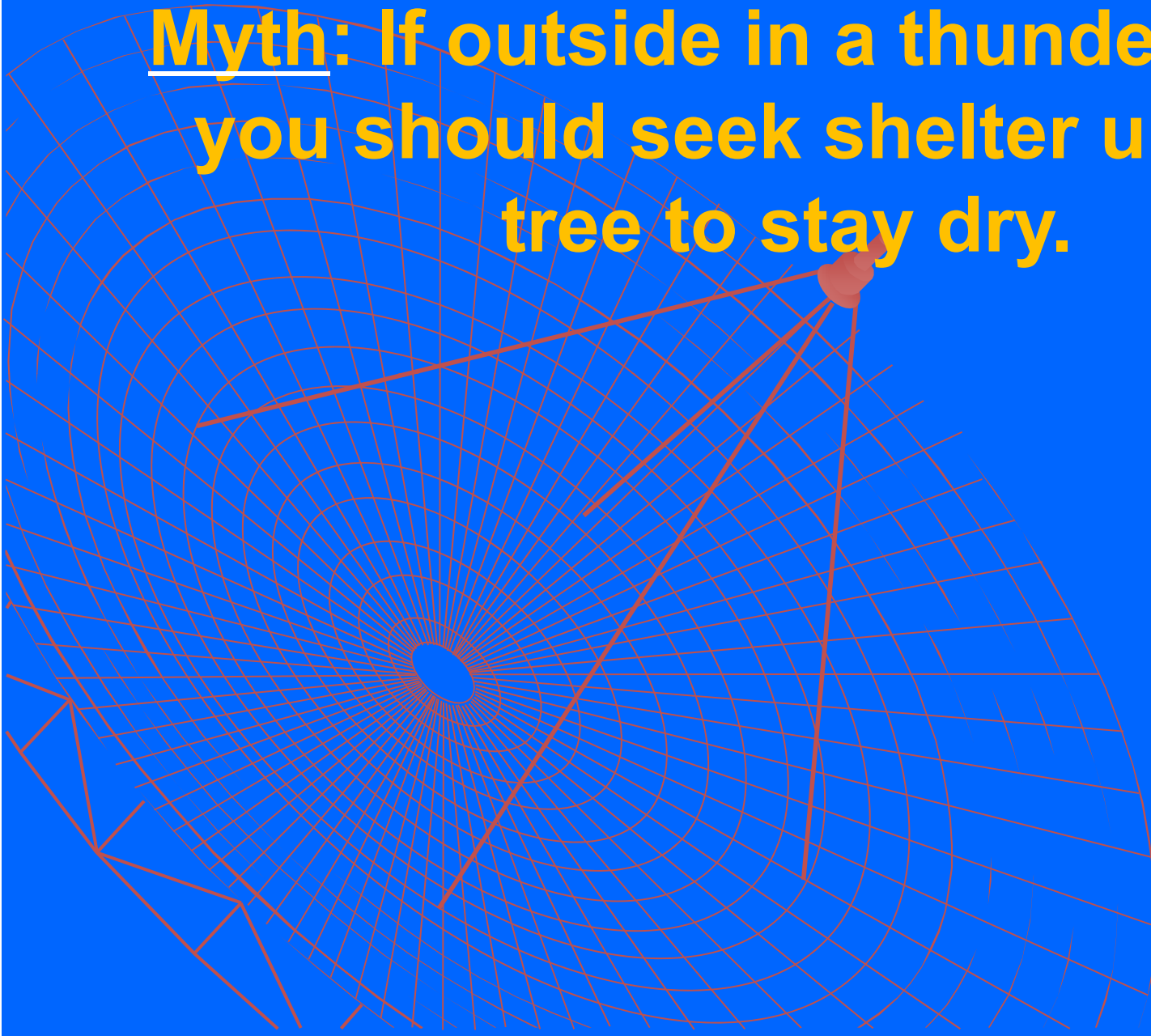


Myth: If it's not raining or there aren't clouds overhead, you're safe from lightning.

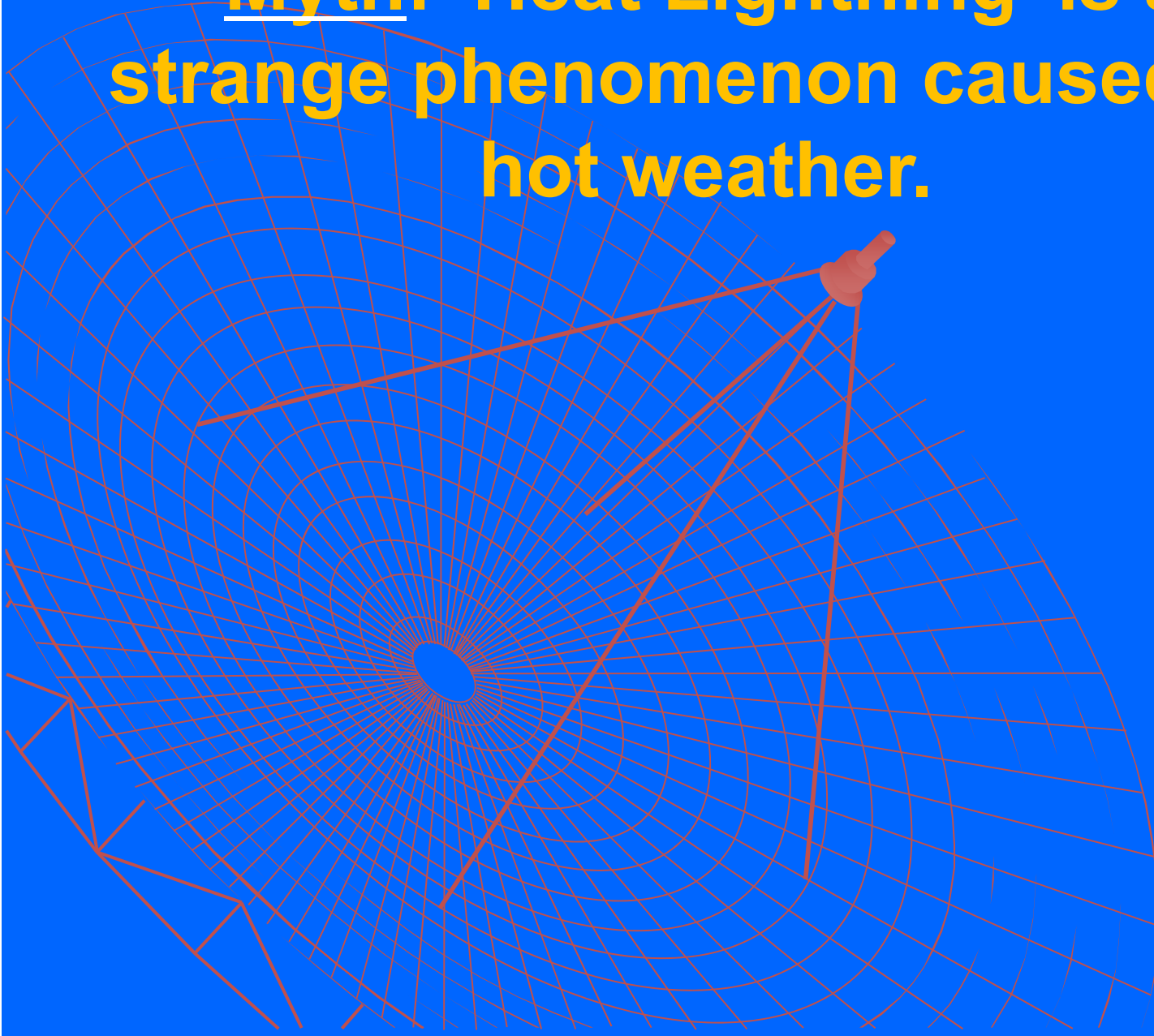
Myth: If thunderstorms threaten while you are outside playing a game, it is okay to finish it before seeking shelter.



**Myth: If outside in a thunderstorm,
you should seek shelter under a
tree to stay dry.**



Myth: 'Heat Lightning' is a
strange phenomenon caused by
hot weather.



Myth: Lightning never strikes the same place twice.

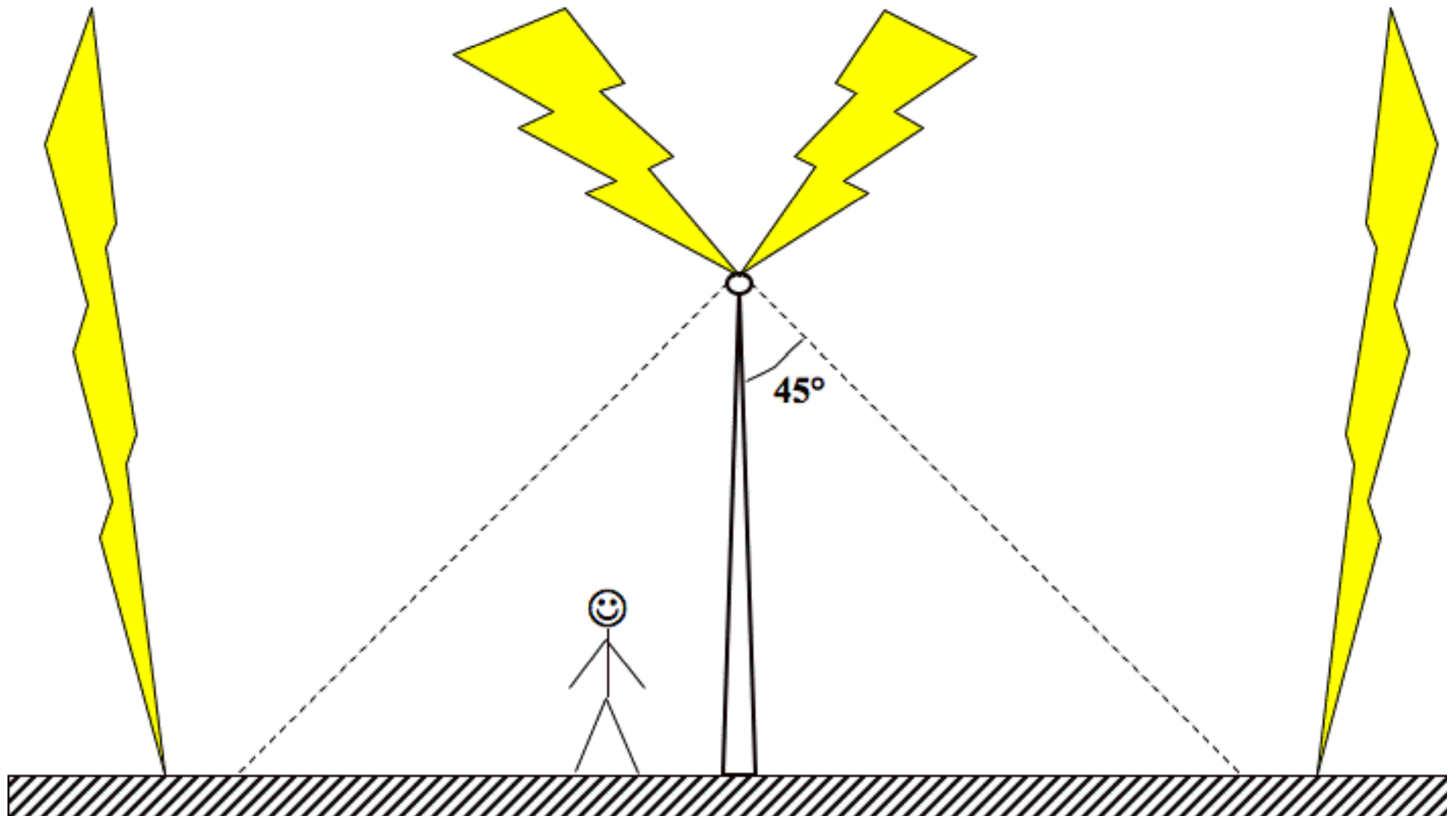


Myth: The automobile's rubber tires you from lightning by insulating you from the ground.

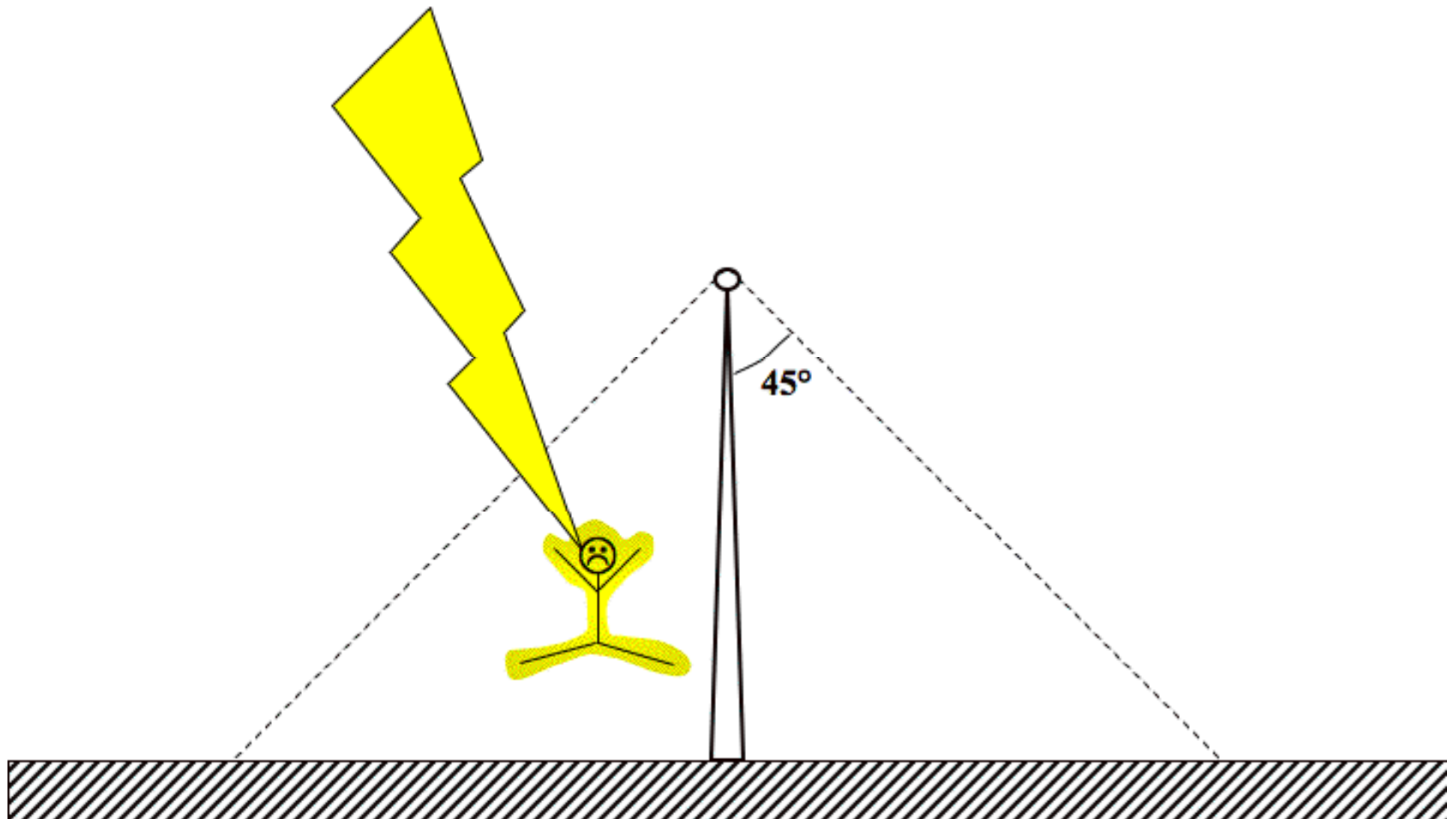


MYTH: Cone Of Protection

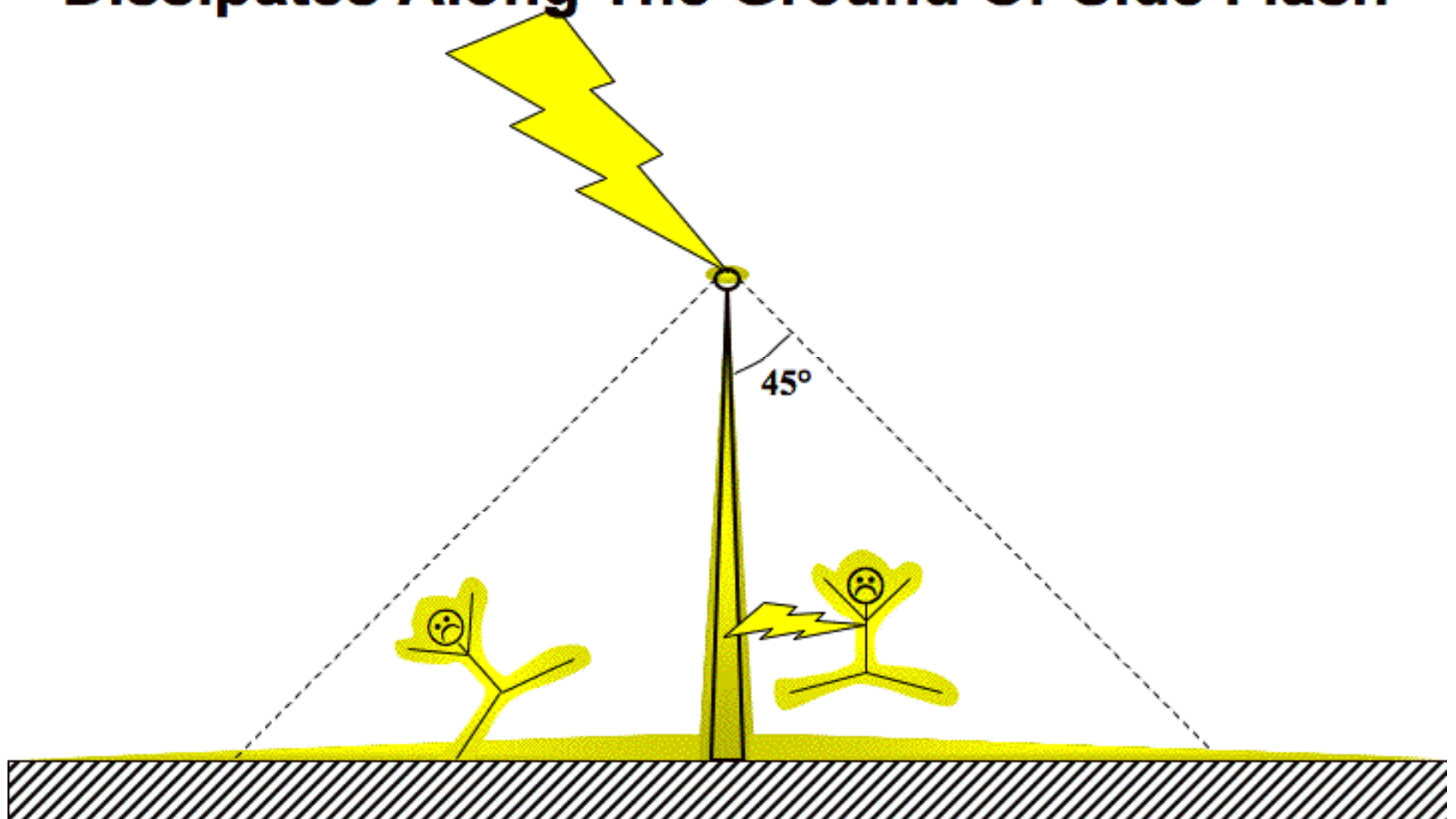
- Lightning won't strike within a cone within 45° of a tall isolated object, since it will attract lightning that close



**REALITY: Lightning Can Easily Strike
Inside The So-Called “Cone Of Protection”**



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

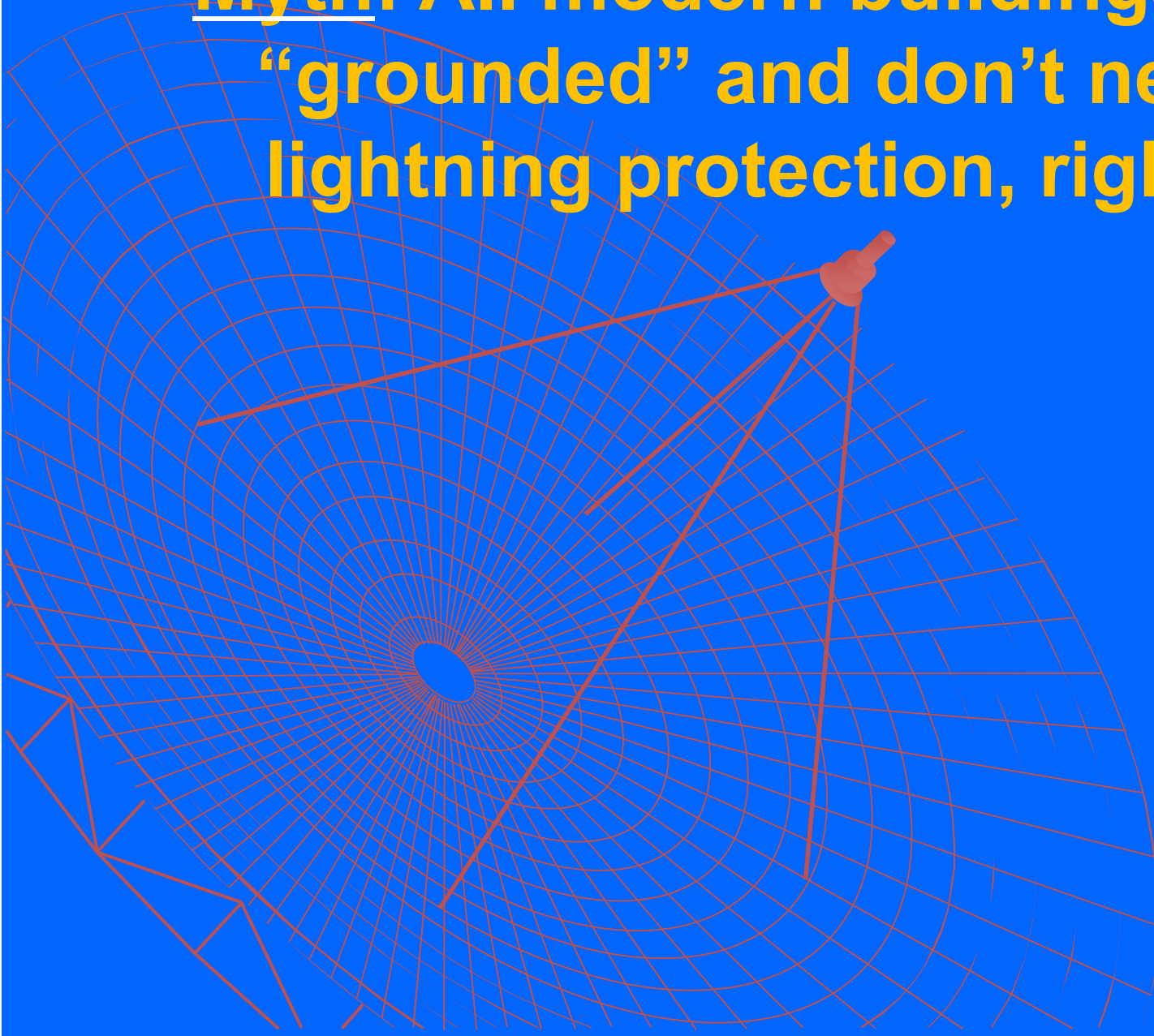


Myth: Average homeowners lightning insurance claim is over \$10,000.

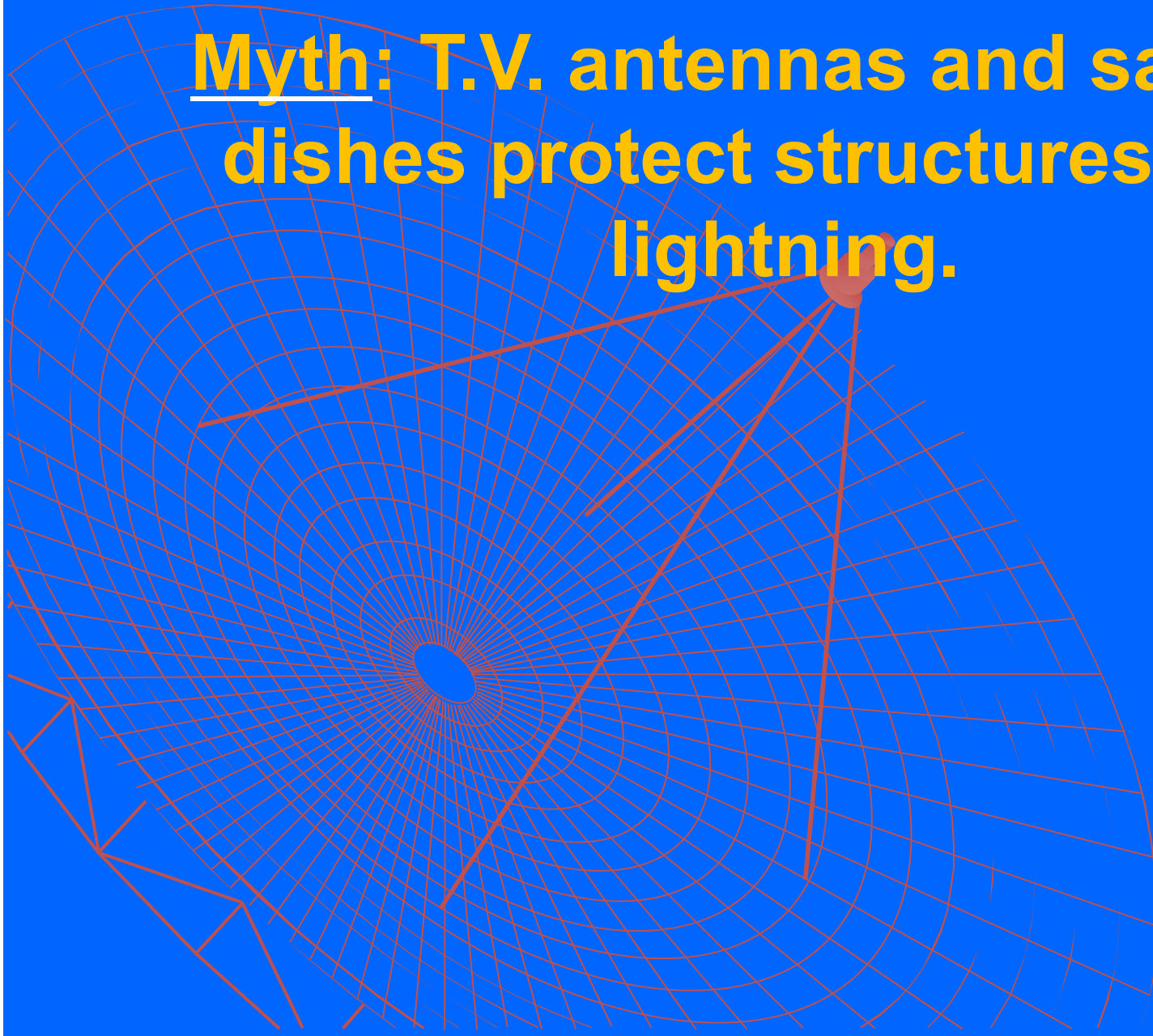
Year	Number of Claims	Value of Claims (\$ millions)	Average Cost Per Claim
2004	278,000	\$735.5	\$2,646
2005	265,700	819.6	3,084
2006	256,000	882.2	3,446
2007	177,100	942.4	5,321
2008	246,200	1,065.5	4,329
2009	185,789	798.1	4,296
2010	213,278	1,033.5	4,846
2011	186,307	952.5	5,112
2012	151,000	969.0	6,400
2013	114,740	673.5	5,869
% change, 2004-2013	-58.7%	-8.4%	121.8%
% change, 2012-2013	-24.0%	-30.5%	-8.3%

Source: Insurance Information Institute, State Farm®.

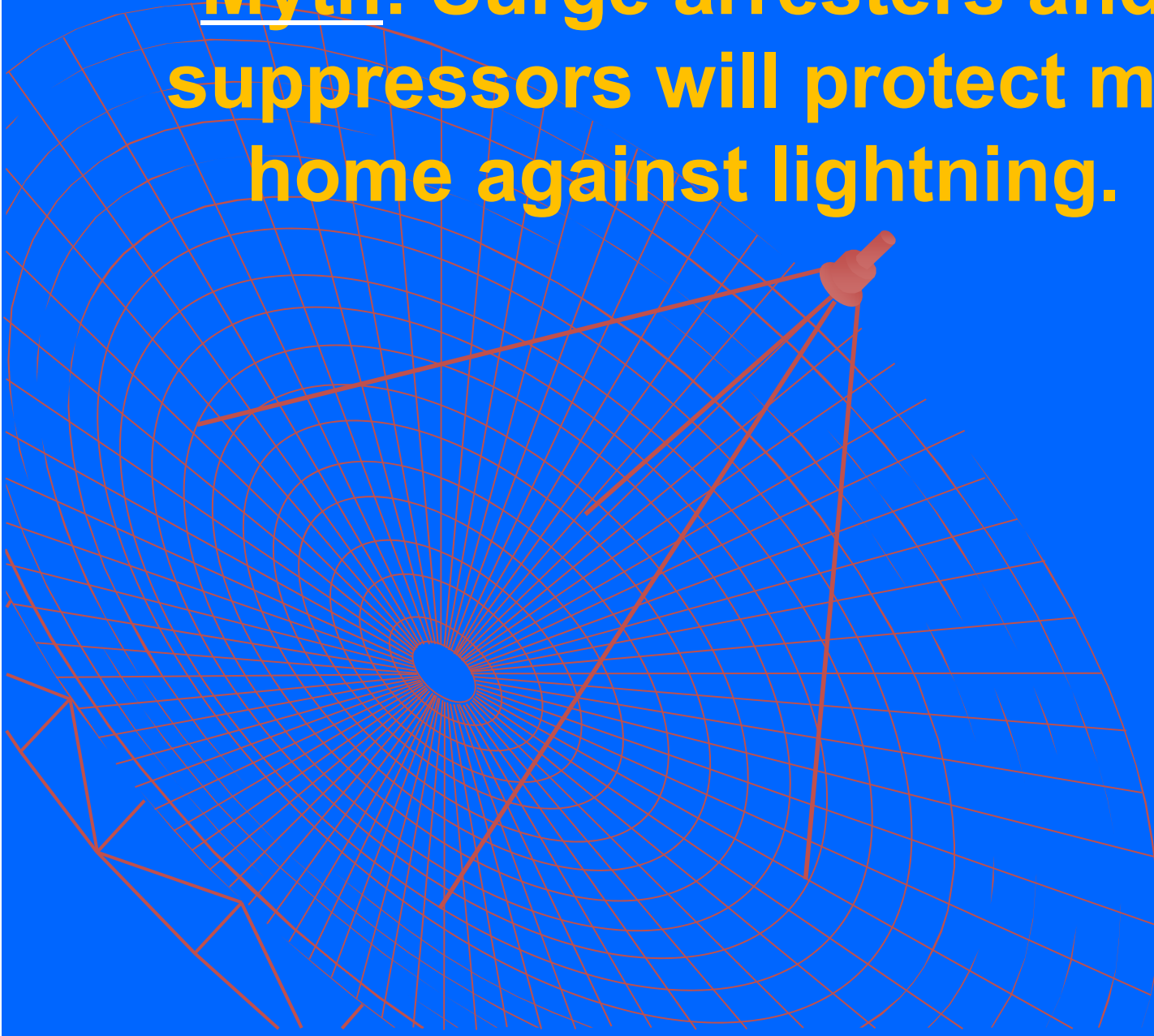
Myth: All modern buildings are
“grounded” and don’t need
lightning protection, right?



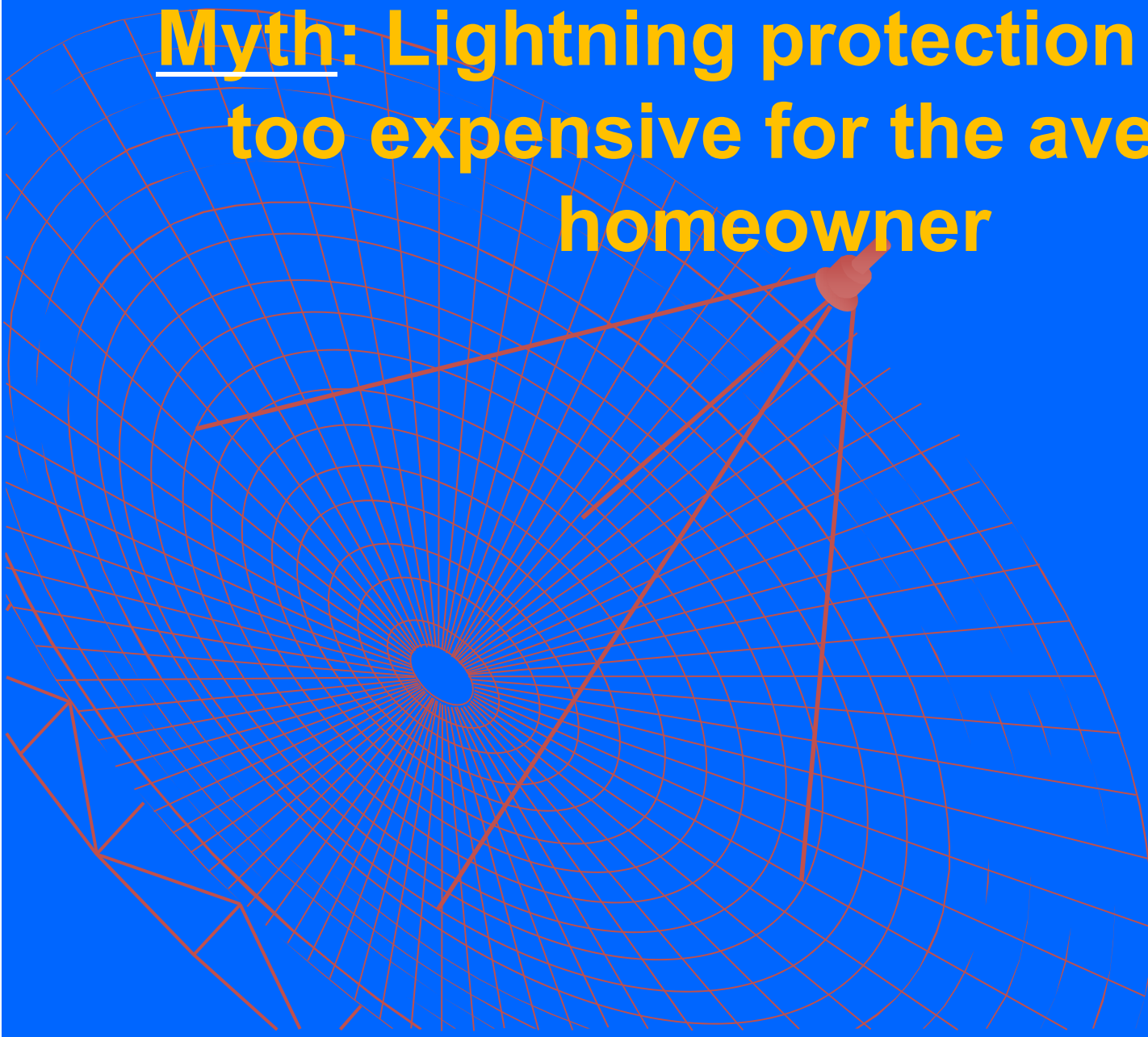
**Myth: T.V. antennas and satellite
dishes protect structures from
lightning.**



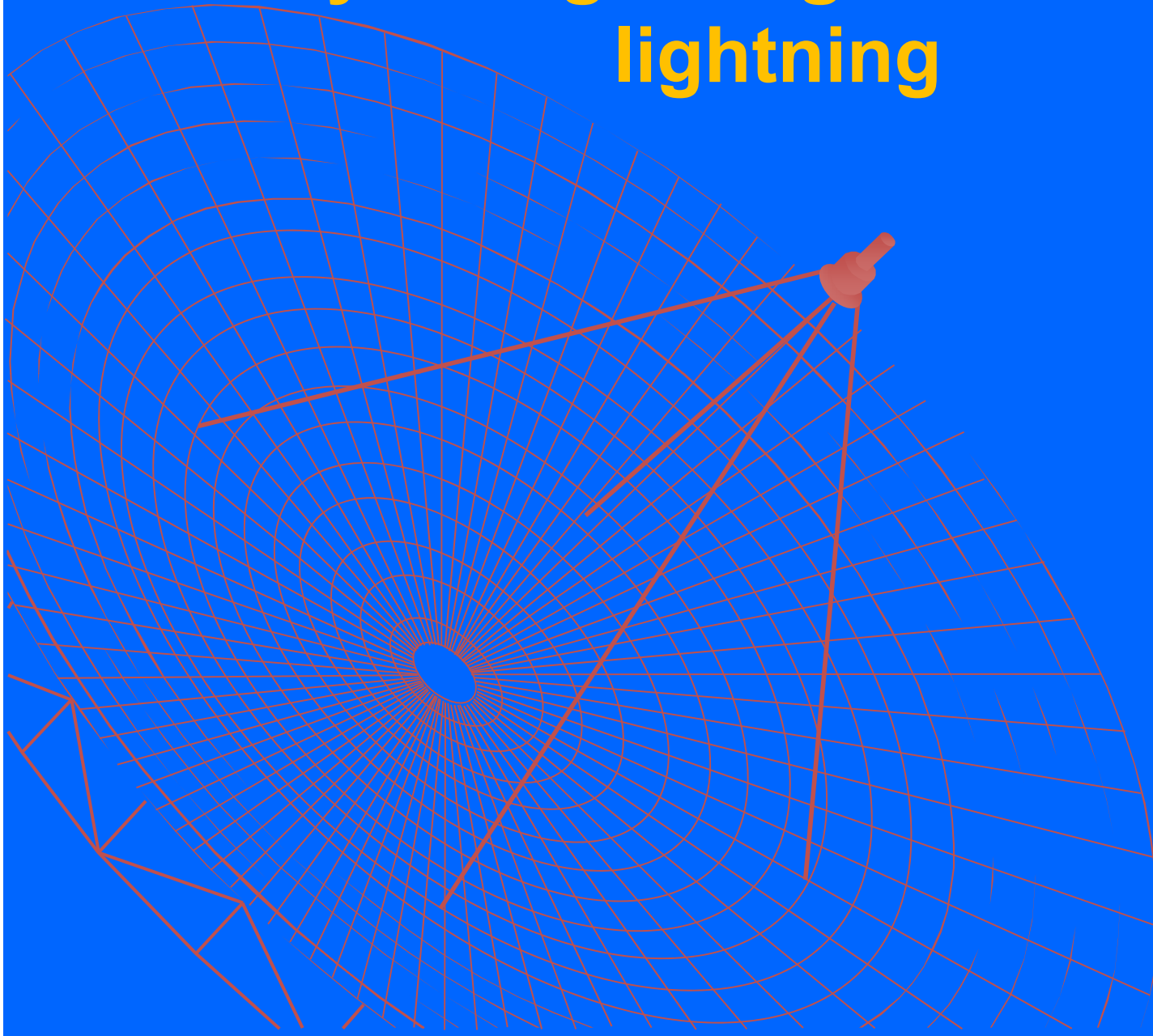
Myth: Surge arresters and suppressors will protect my home against lightning.



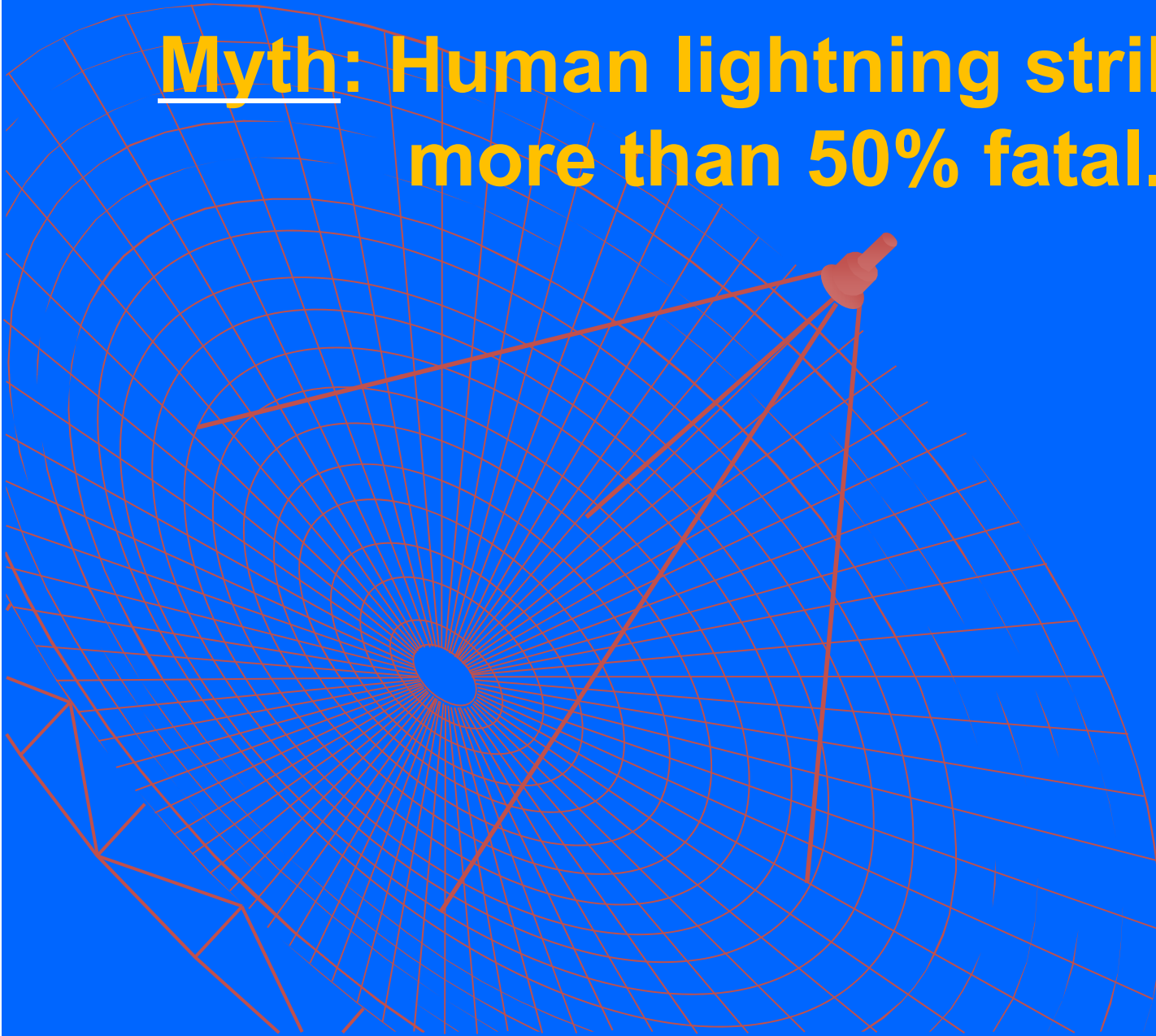
Myth: Lightning protection is way
too expensive for the average
homeowner



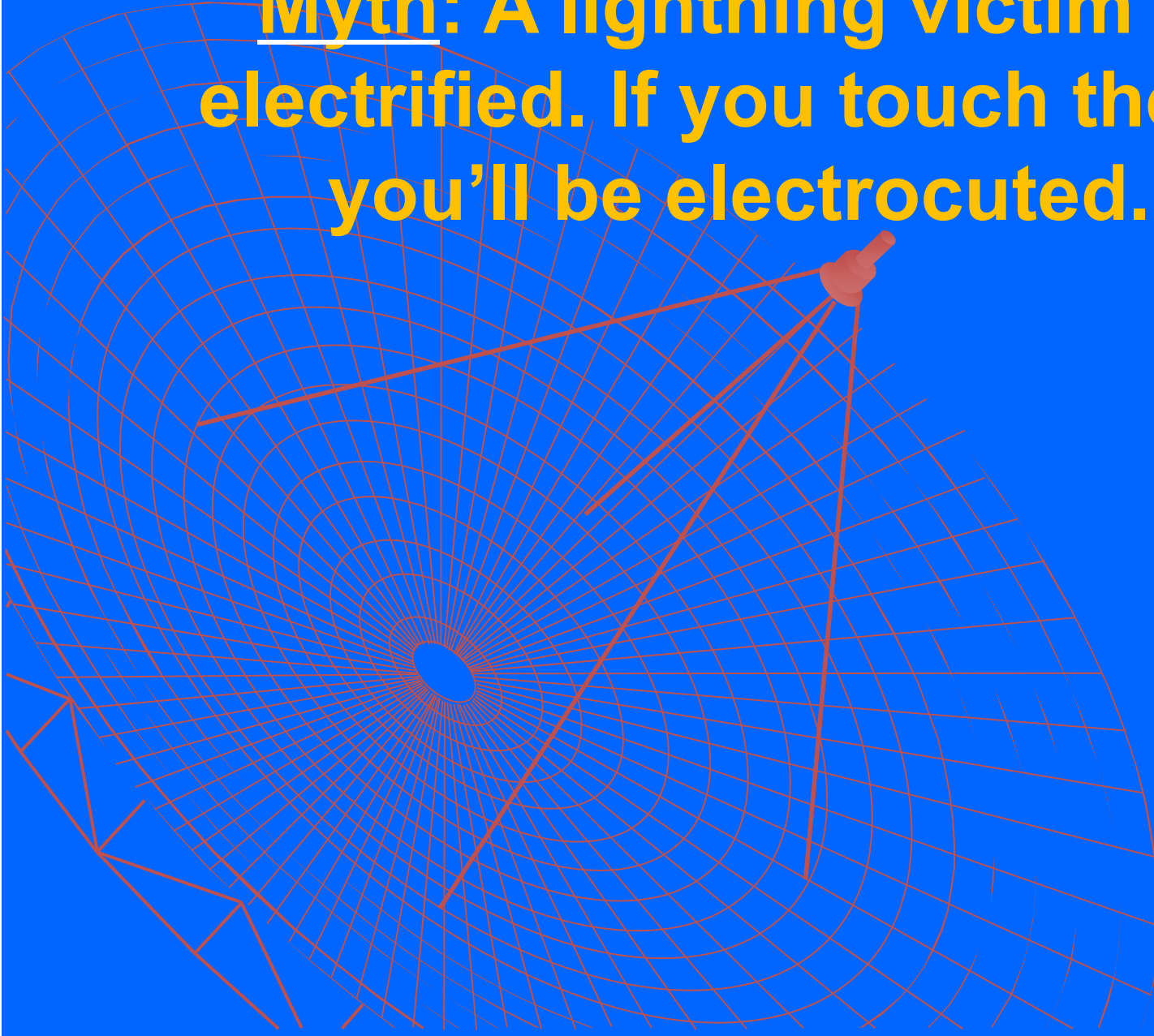
Myth: Lightning rods attract lightning



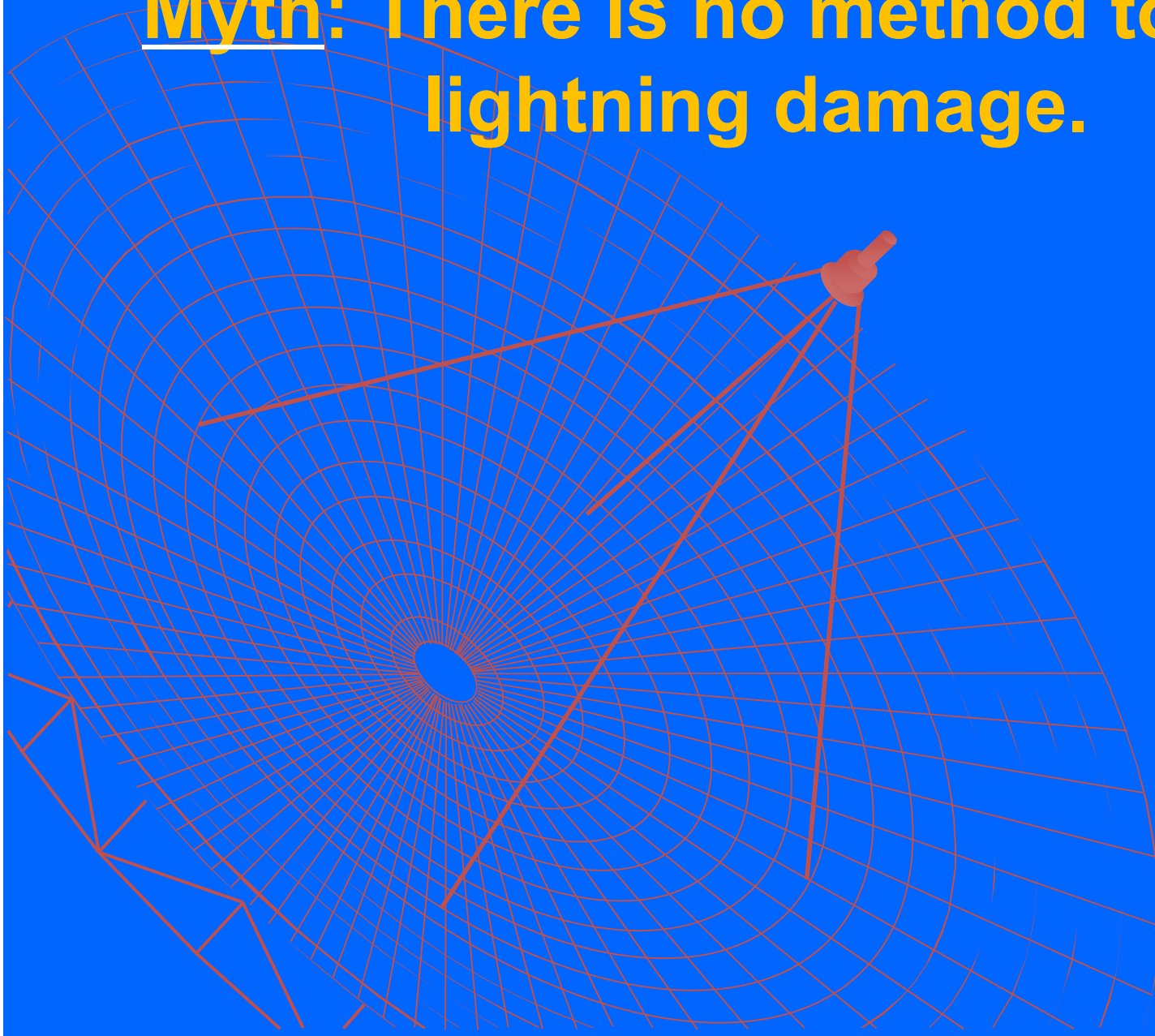
Myth: Human lightning strikes are more than 50% fatal.



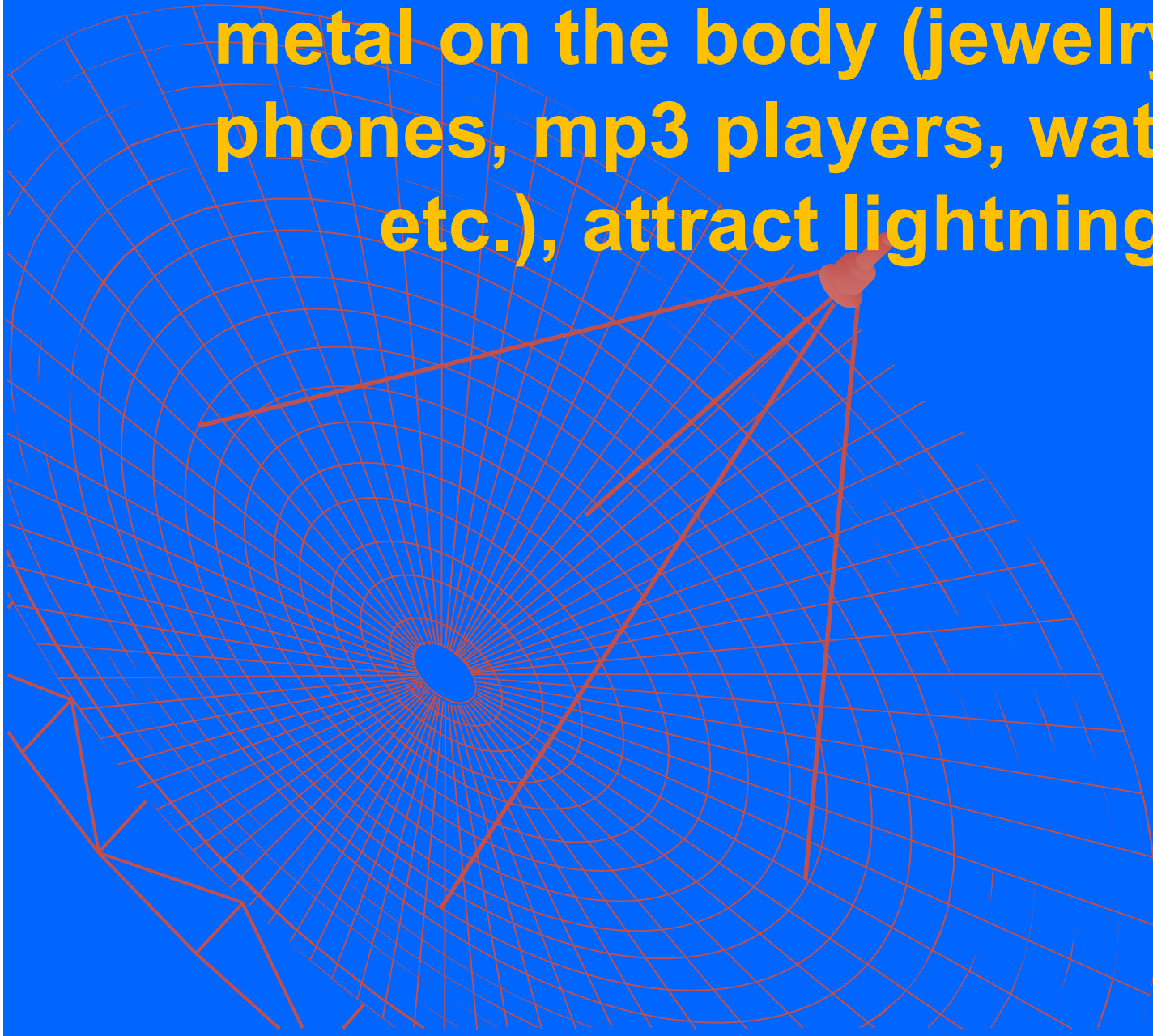
Myth: A lightning victim is electrified. If you touch them, you'll be electrocuted.



Myth: There is no method to stop lightning damage.



Myth: Structures with metal, or metal on the body (jewelry, cell phones, mp3 players, watches, etc.), attract lightning.



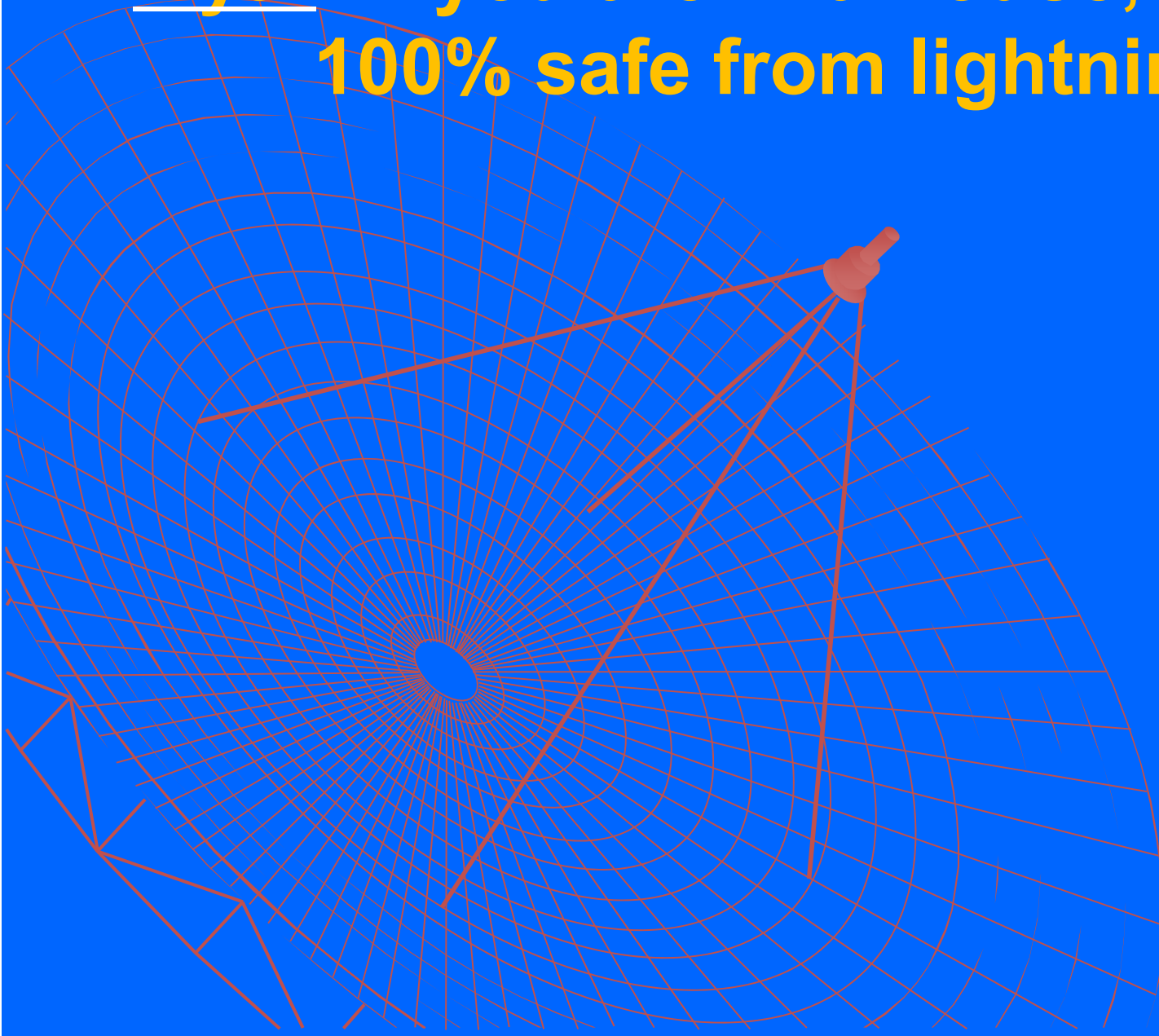
Myth: To stop lightning strike in your home, put the antenna coax connector plug in a glass cup.



Myth: To stop lightning strike in your home, put the antenna coax connector plug in a glass cup.



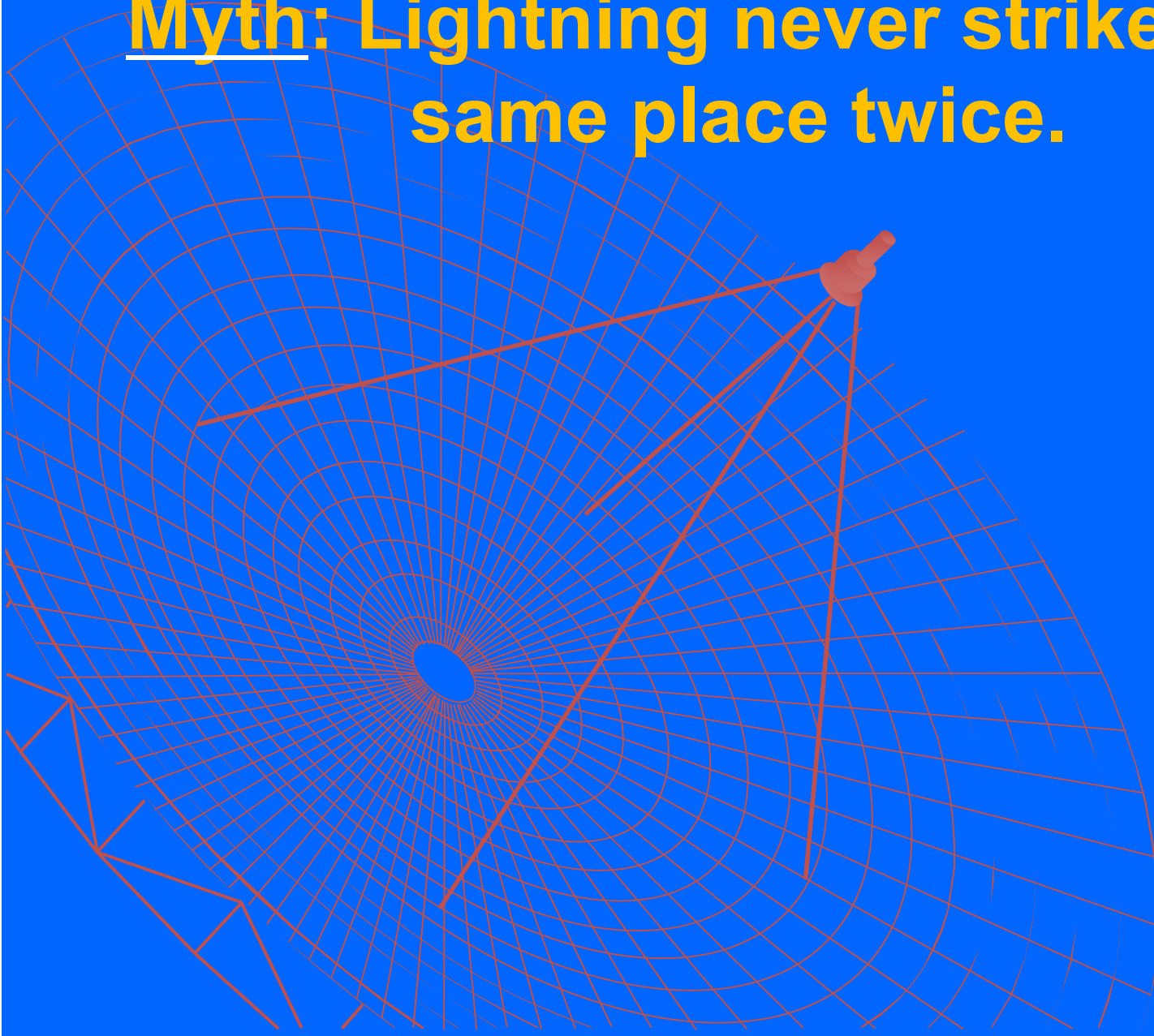
Myth: If you are in a house, you are
100% safe from lightning.



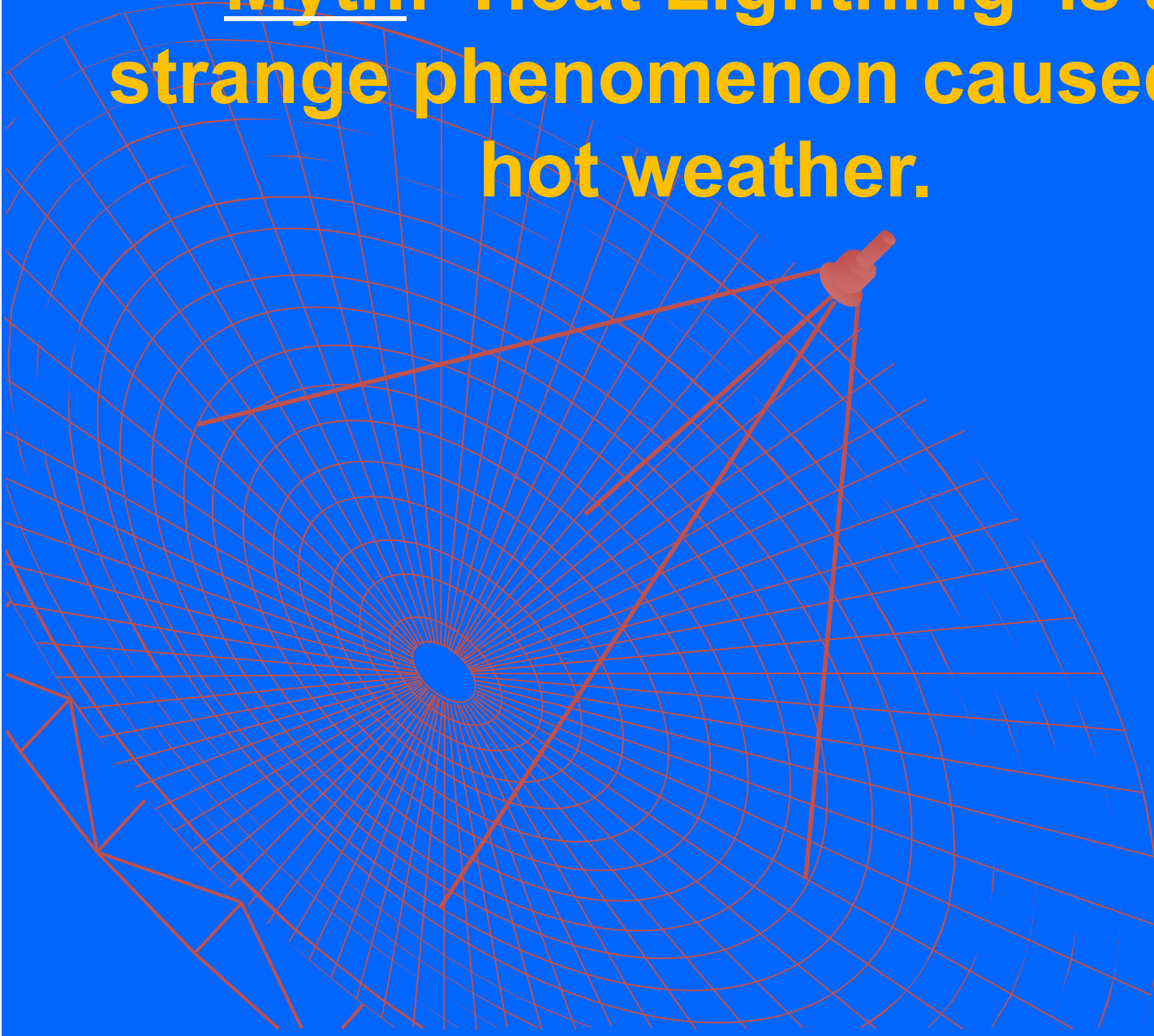
Myth: The automobile's rubber tires you from lightning by insulating you from the ground.



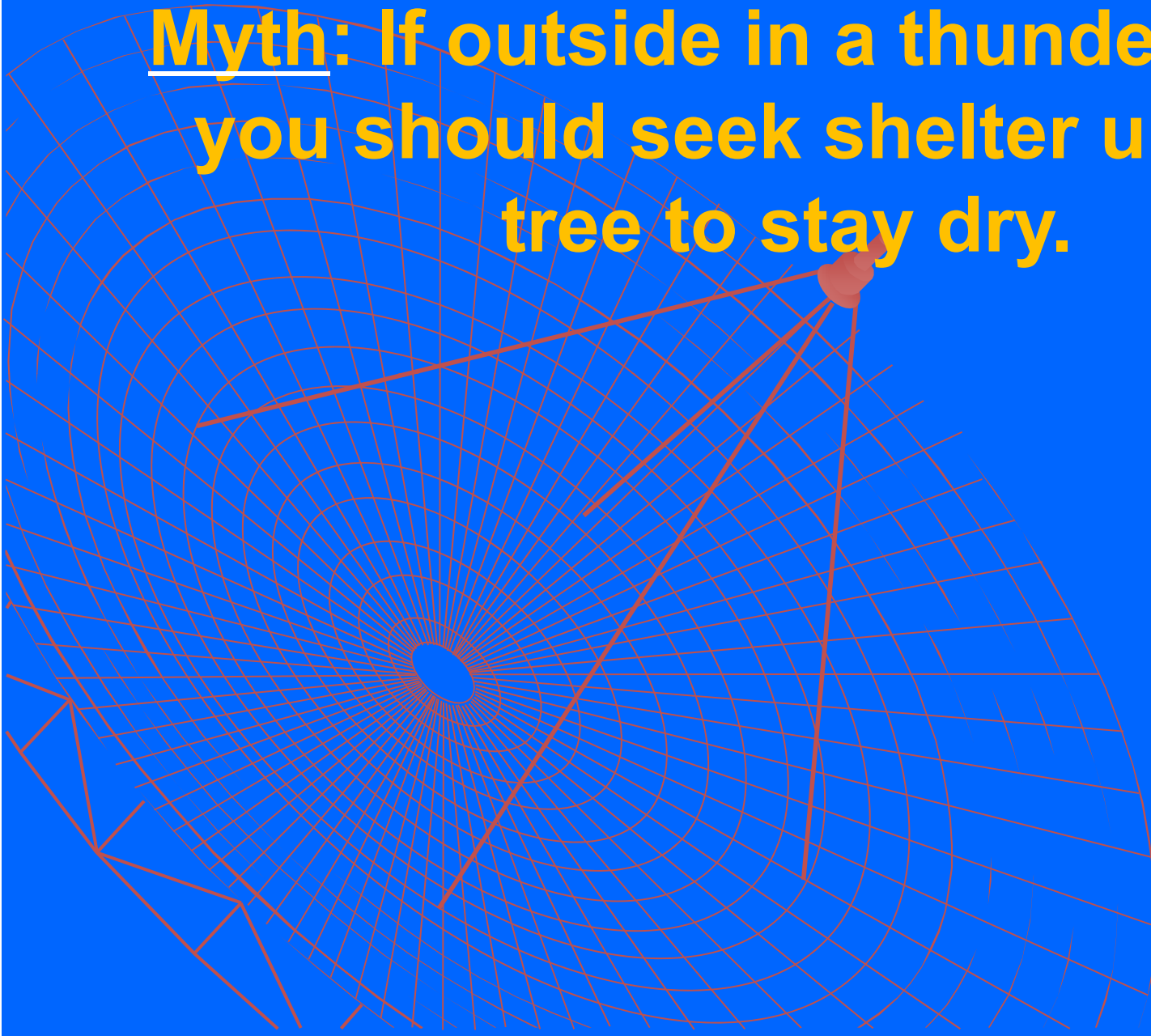
Myth: Lightning never strikes the same place twice.



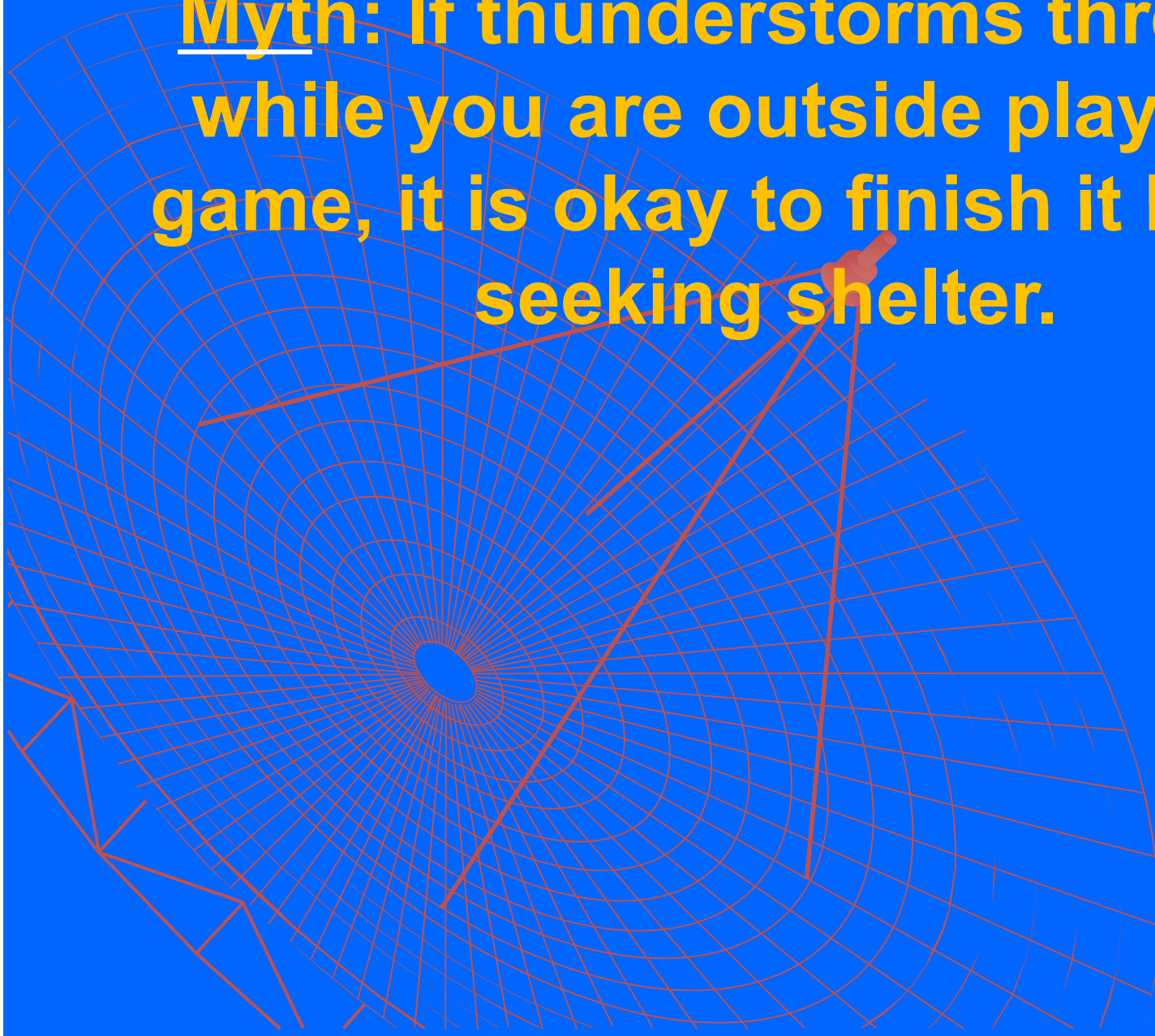
Myth: 'Heat Lightning' is a
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tree to stay dry.



Myth: If thunderstorms threaten while you are outside playing a game, it is okay to finish it before seeking shelter.





Myth: If it's not raining or there aren't clouds overhead, you're safe from lightning.



◆ What is not lightning protection?

- Early steamer Emission – EME
 - ◆ Radioactive
 - ◆ Pulse Voltage
 - ◆ Sparking – Controlled Leader Trigger (CLT)
- Lightning Elimination
 - ◆ Dissipation Array System (DAS)
 - ◆ Charge Transfer System (CTS)
- Not allowed by
 - ◆ DoD
 - ◆ IEC
 - ◆ IEEE
 - ◆ NFPA
 - ◆ UL



SEAWORLD ORLANDO LIGHTNING INCIDENT

**FAILURE OF THE SECOND GENERATION
EARLY STREAMER EMISSION LIGHTNING ROD**



**By
L.A. Martone & I Rubiah
September 2012
E-mail: california@ieee.org**

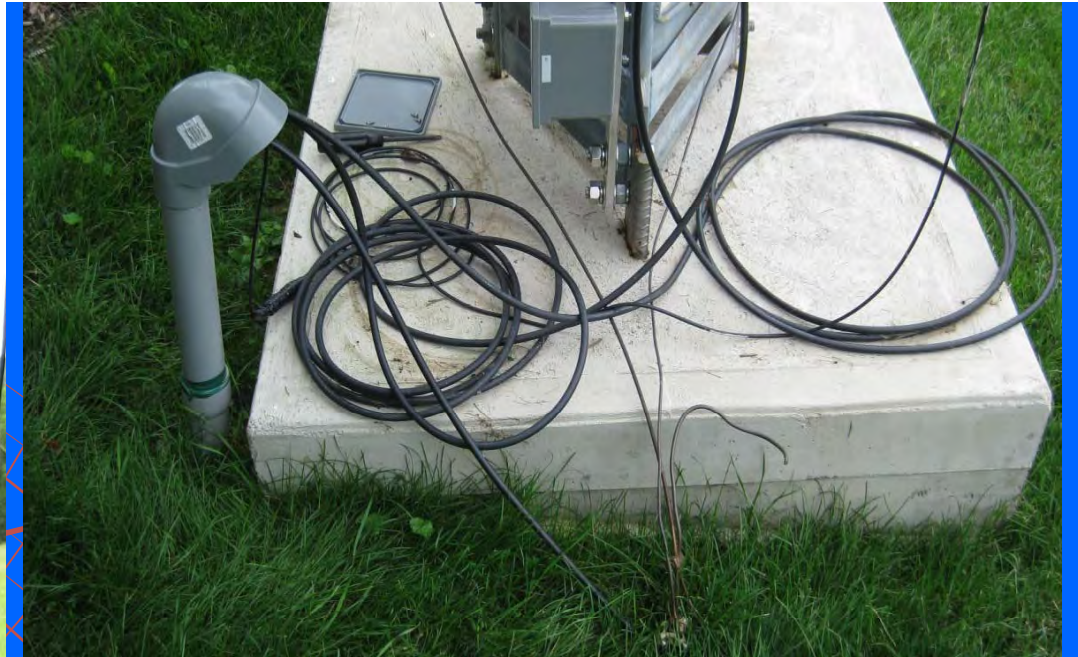
Possible Problems



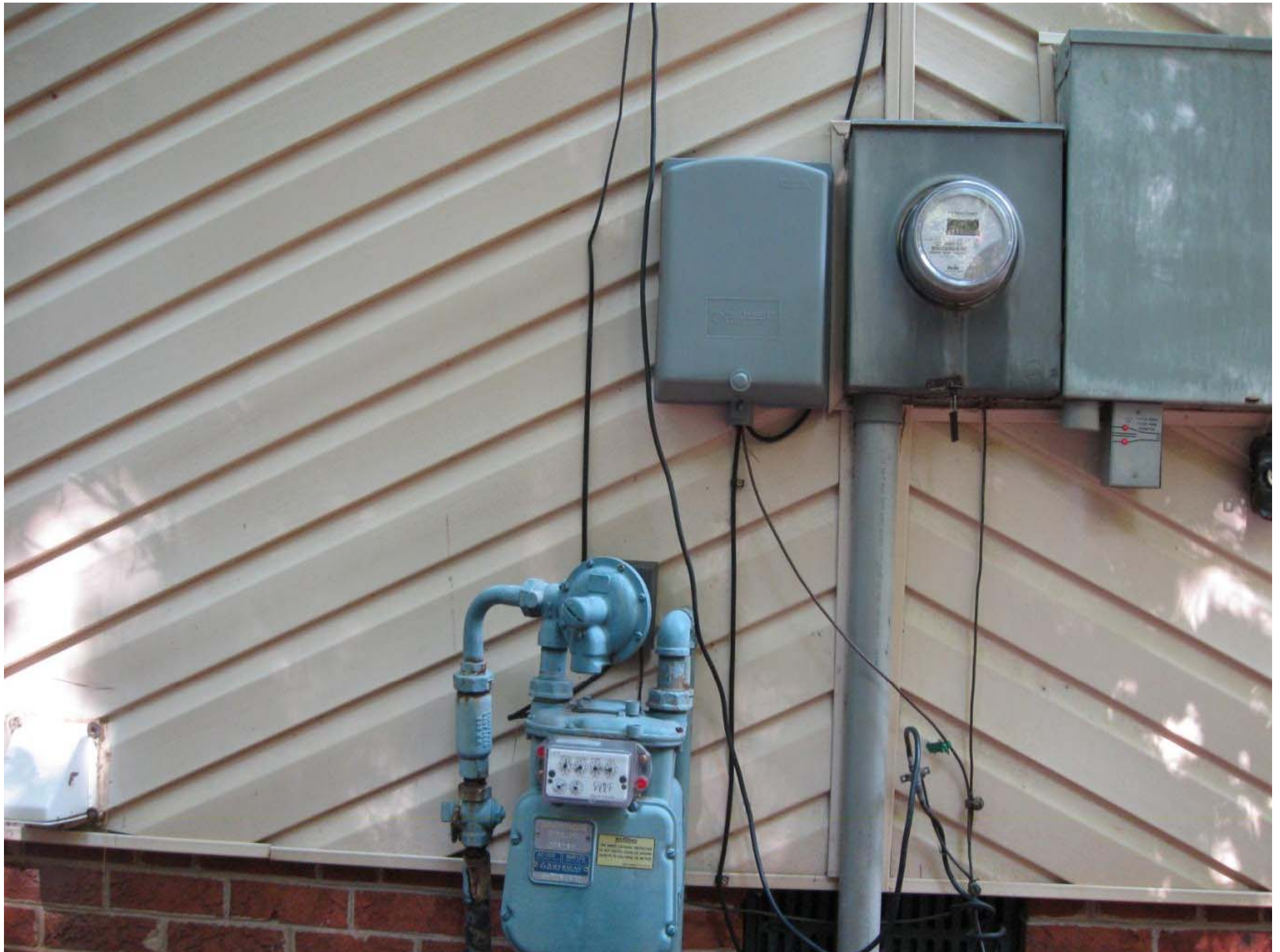


**Antenna Coax
& Lighting
Cables**

**Ground
Wire**



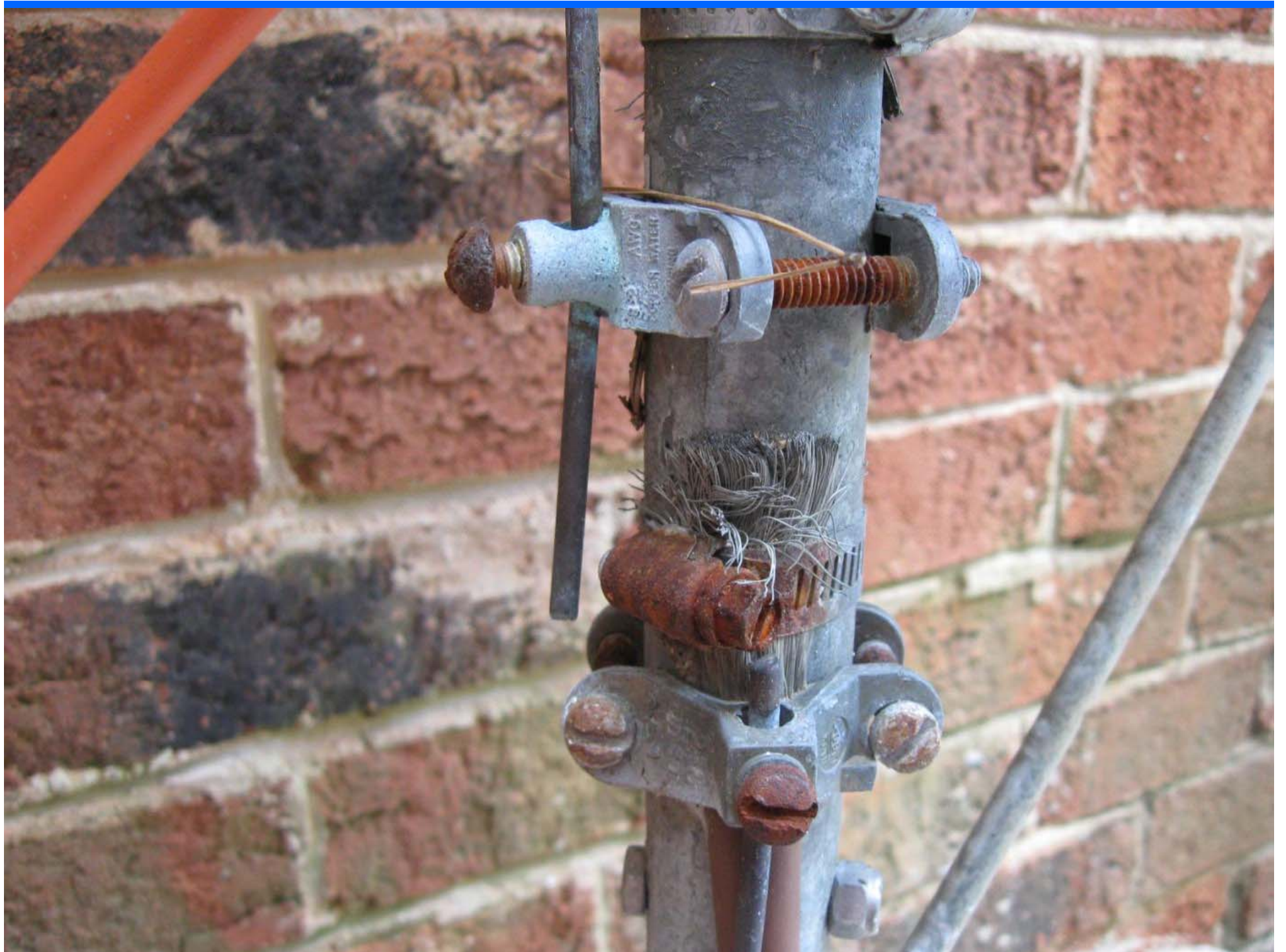




























ECP-1
MUNITIONS
STORAGE AREA
ALL VISITORS
MUST CALL 4-4119
FOR ENTRY

When turning off the radio:

Please follow the “rules of disagagement”

- Physical unplug all cables from the single point ground to ham equipment
- Ground all antennas – Best outside the station building
- Ground everything which enter the shack
- Unplug AC power at wall outlets

If one forgets and you have not followed the “rules of disagagement”, a near-by strike might migrate and bypass your lightning protection system

Disclaimer

Not an expert in grounding and/or in lightning protection

Have some personal experience with lightning, lightning damage and lightning protection

Never worked professionally in any capacity in lightning or protection from lightning

Suggested lightning protection procedures may reduce total damage

MOTHER NATURE

She can be kind...



Or Not



...and unpredictable!



