Lightning Protection for the Radio Amateur

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Rule #1

Lightning cannot be prevented or eliminated.

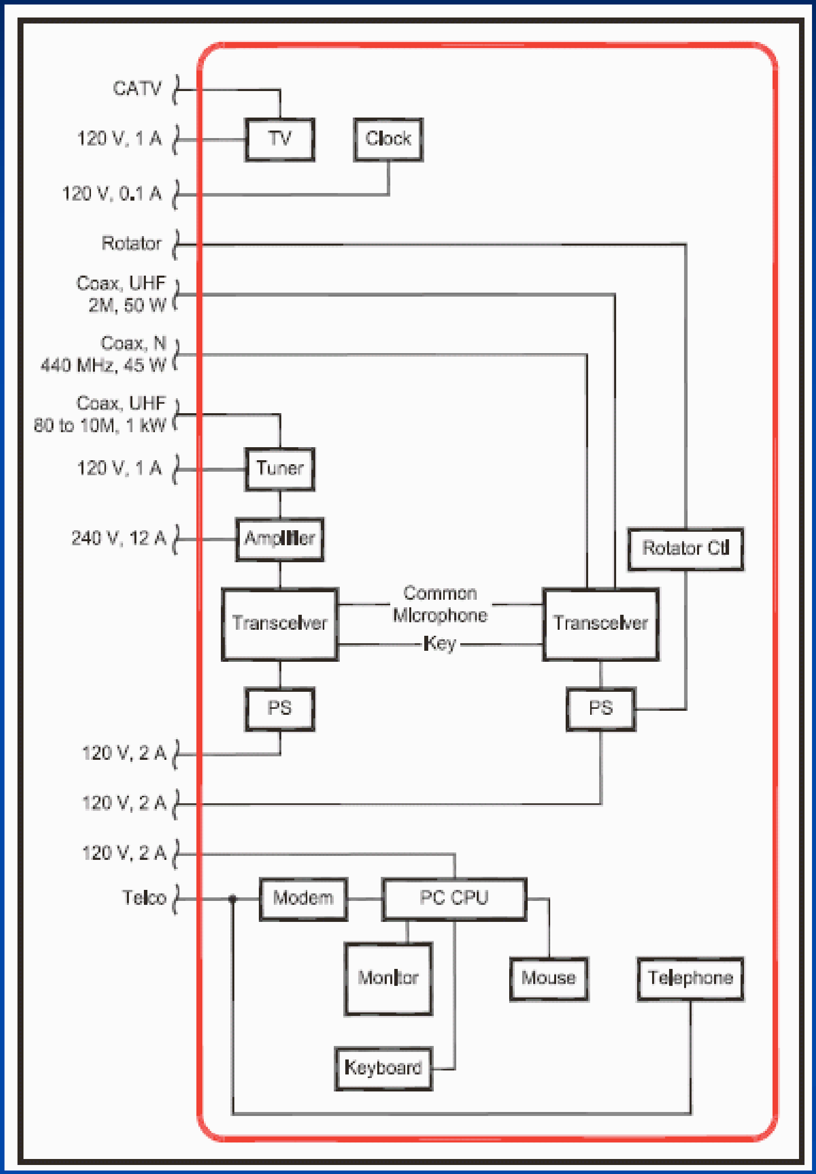
Lightning Protection is...

Education!

ARRL has lots of good info —
over 100 articles, dating back to 1916!
Series of 3 articles from *QST,* 6-8/2002 (on web)
(remember rule #1)

- Common sense
- Follow accepted practices
- Careful installation, and
- Regular maintenance!!

Catalog what needs protecting



Use protection devices engineered for the type of I/O line to be protected.

Risk Management

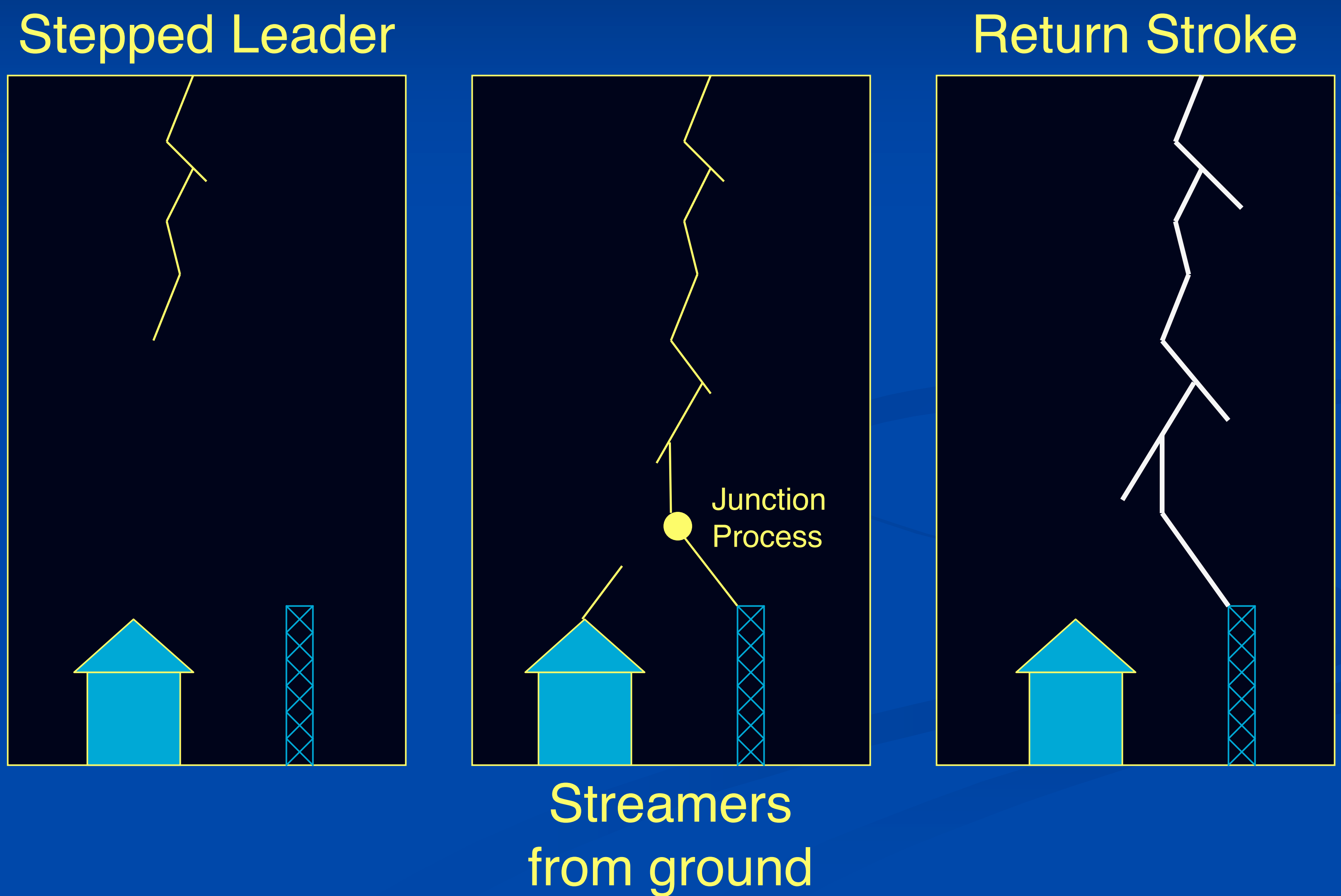
- **Protection plan**:
  1) Intercept lightning with air terminal
  2) Direct lighting current to earth in controlled manner
  3) Dissipate lightning current in earth
  4) Suppress induced transients with suppression devices

- **Outdoor equipment** is exposed to primary energy of lightning strikes and can be difficult to protect without interfering with operation.

- **Indoor equipment** is exposed to secondary energy of lightning strike and is relatively easy to protect.

- **Balance the cost and effort** involved in providing lightning protection against that to repair or replace potentially damaged equipment.

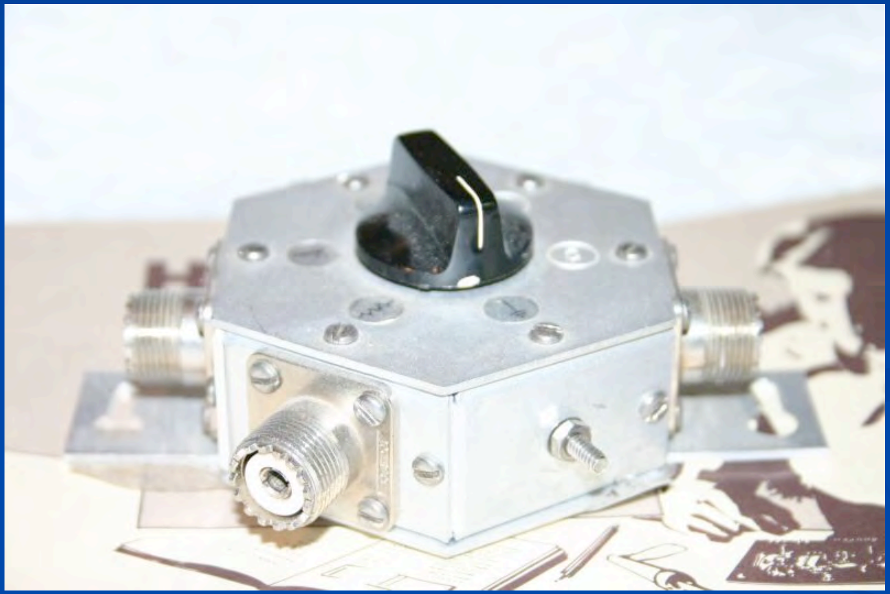
Tell me about how a lightning strike occurs…



Types of Hazards

1) Static charging (e.g., wind static)

Help for static charging



Do not confuse this with lightning protection!

Types of Hazards

1) Static charging (e.g., wind static)

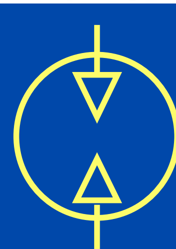
2) Nearby lightning

Transient Suppression for Nearby Strikes

TransZorb

Not for RF!!

Spark Gap



OK for RF
Replaceable tube

MOV

Not for RF!!

More on Transient Suppression

Use all 3 types in parallel:

- Telephone – between:
  - red & green
  - red and ground
  - green and ground

- Power – between:
  - hot & neutral
  - hot & ground
  - neutral & ground

- Rotor control – between each wire and ground

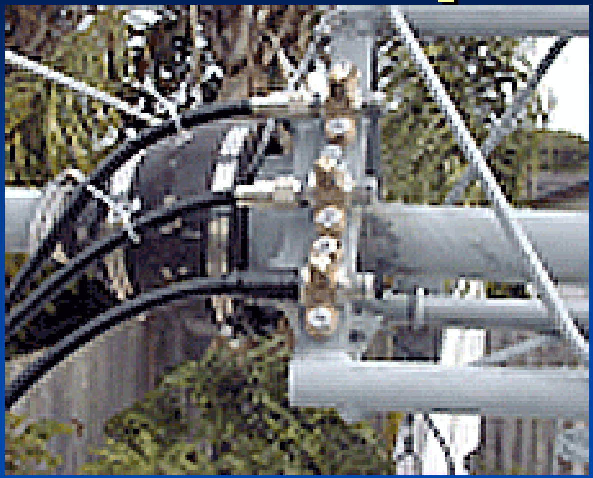
Types of Hazards

1) Static charging (e.g., wind static)

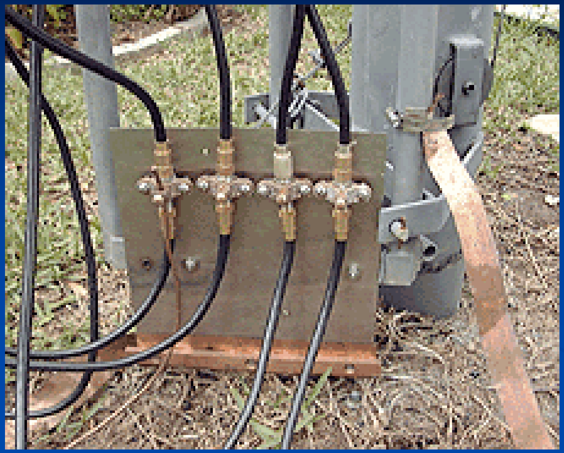
2) Nearby lightning

3) Near-miss (unsuccessful leader)

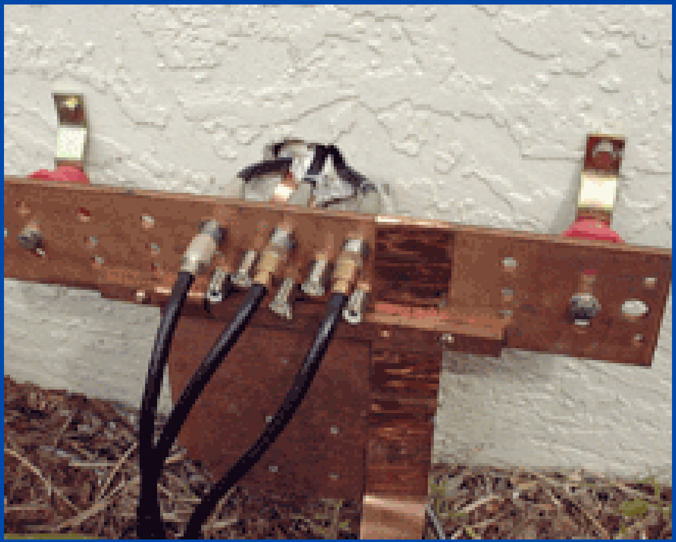
Examples of Grounding



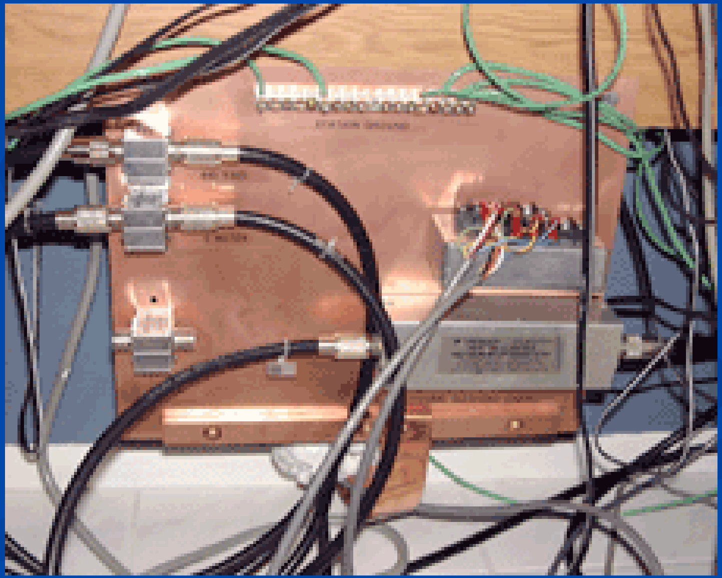
Coax shields grounded at top of tower



Coax shields grounded at bottom of tower



Single point ground outside of house
(point of entry)



Single point ground inside shack

Photos Courtesy of Bill Otten, KC9CS

Commercial Hardline Entry point

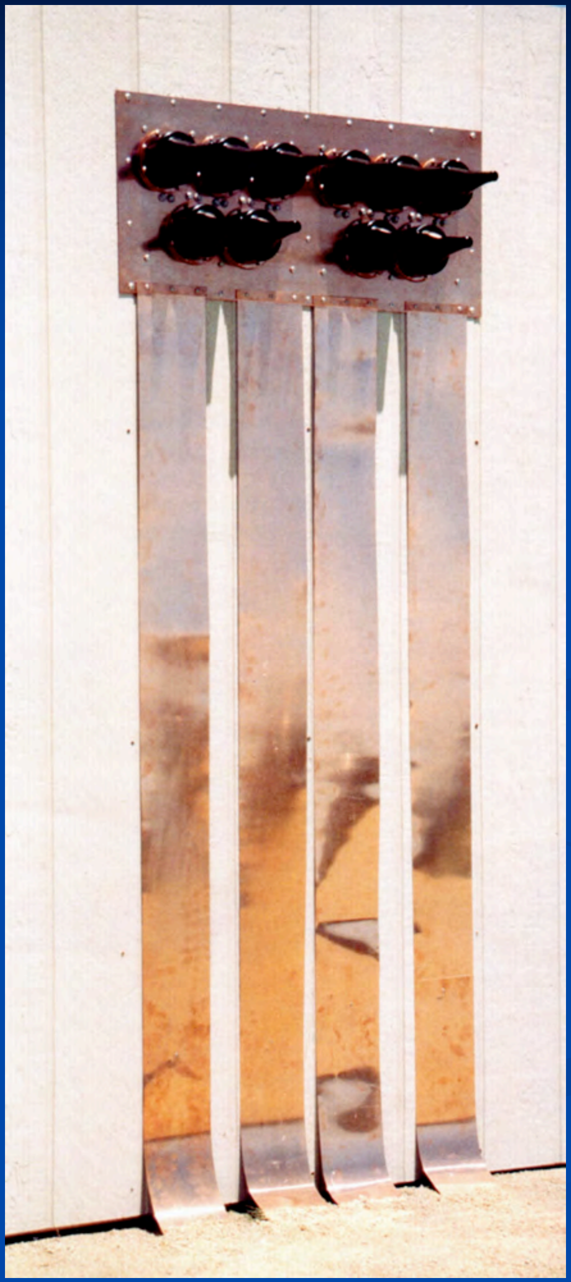
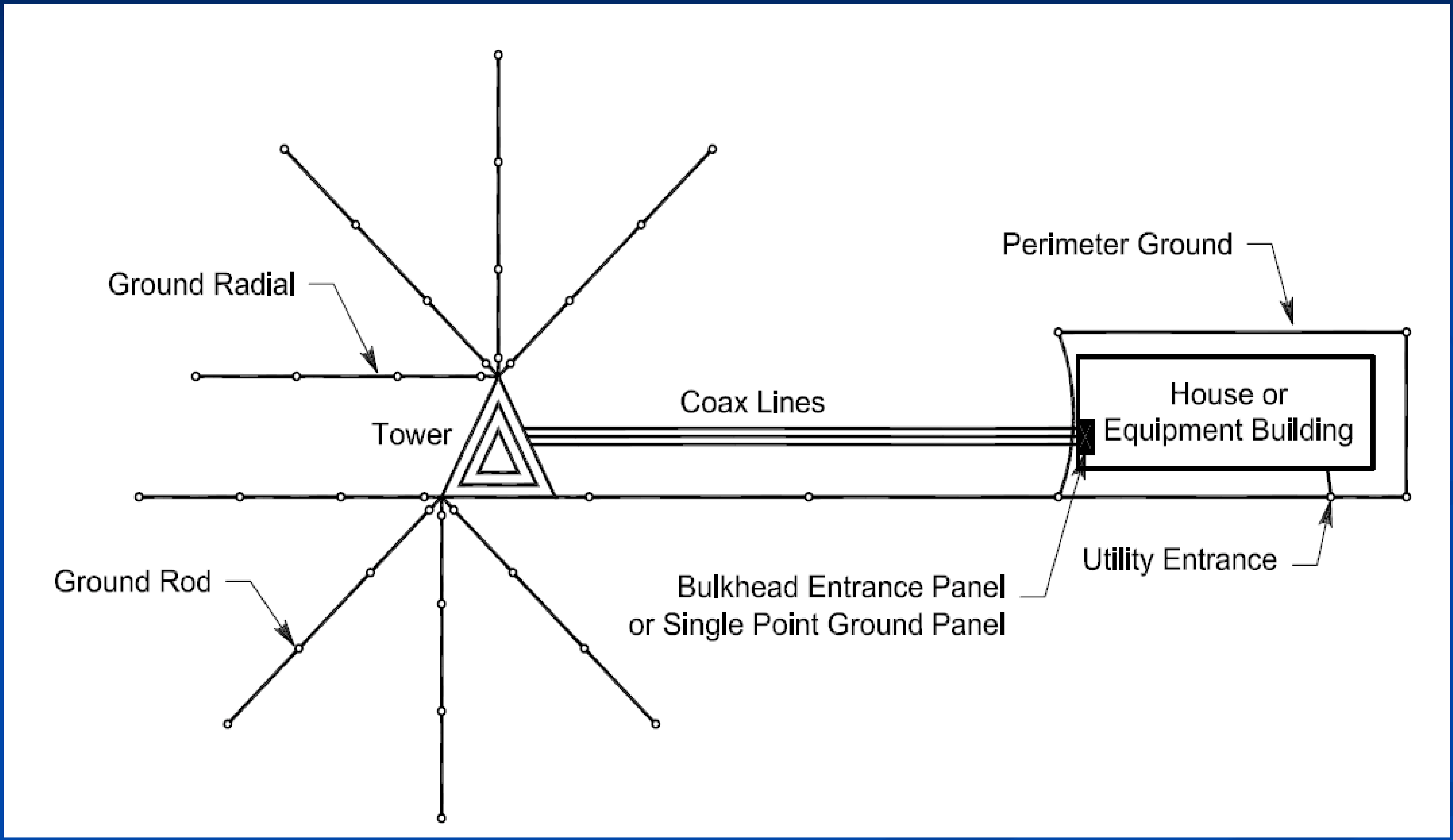


Photo Courtesy of PolyPhaser

Tower Grounding



Also: Ufer ground

Courtesy of PolyPhaser

Types of Hazards

1) Static charging (e.g., wind static)

2) Nearby lightning

3) Near-miss (unsuccessful leader)

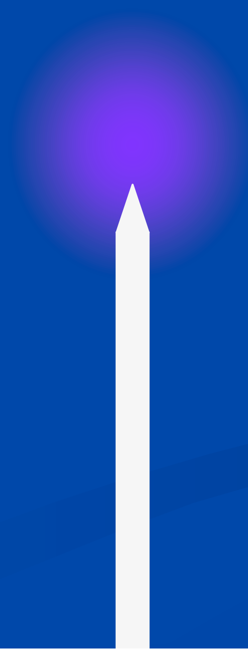
4) Direct strike

Corona

a.k.a. “St. Elmo’s Fire”

In the presence of strong electric fields, air will ionize (become conductive) and glow blue-purple.

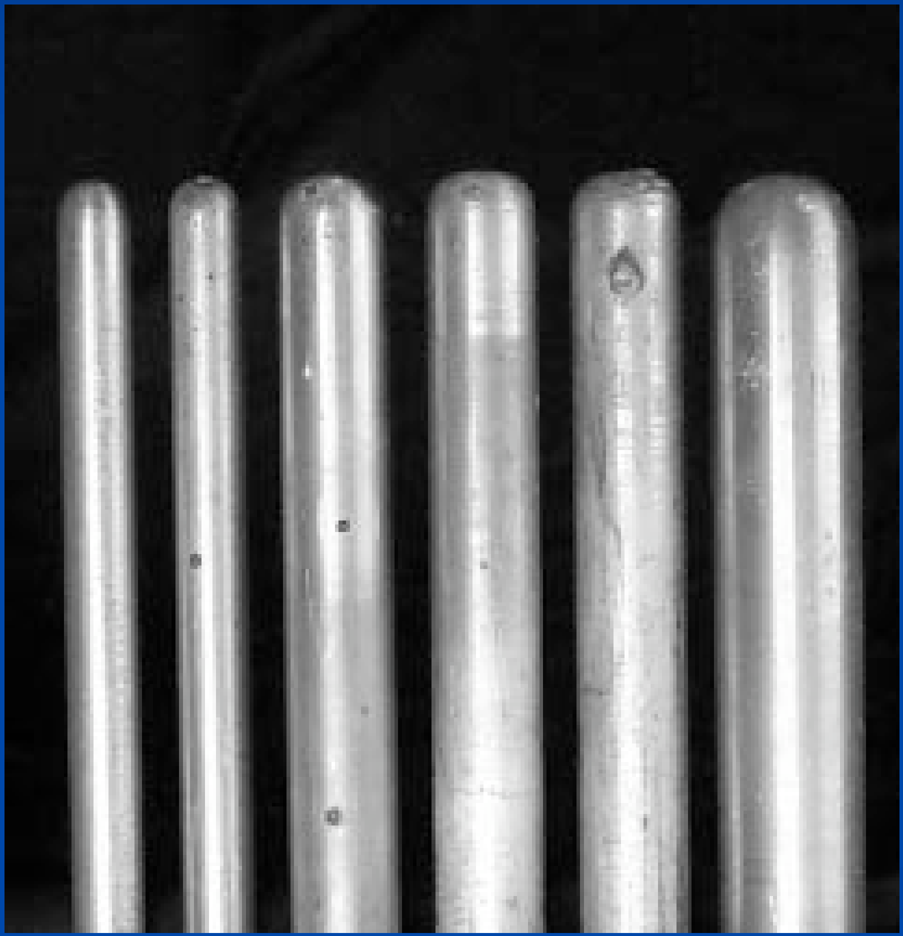
The ionized air then acts as a shield.



Sharp pointed conductors “focus” the field and enhance this effect.

Direct Strikes

What makes a good lightning rod?



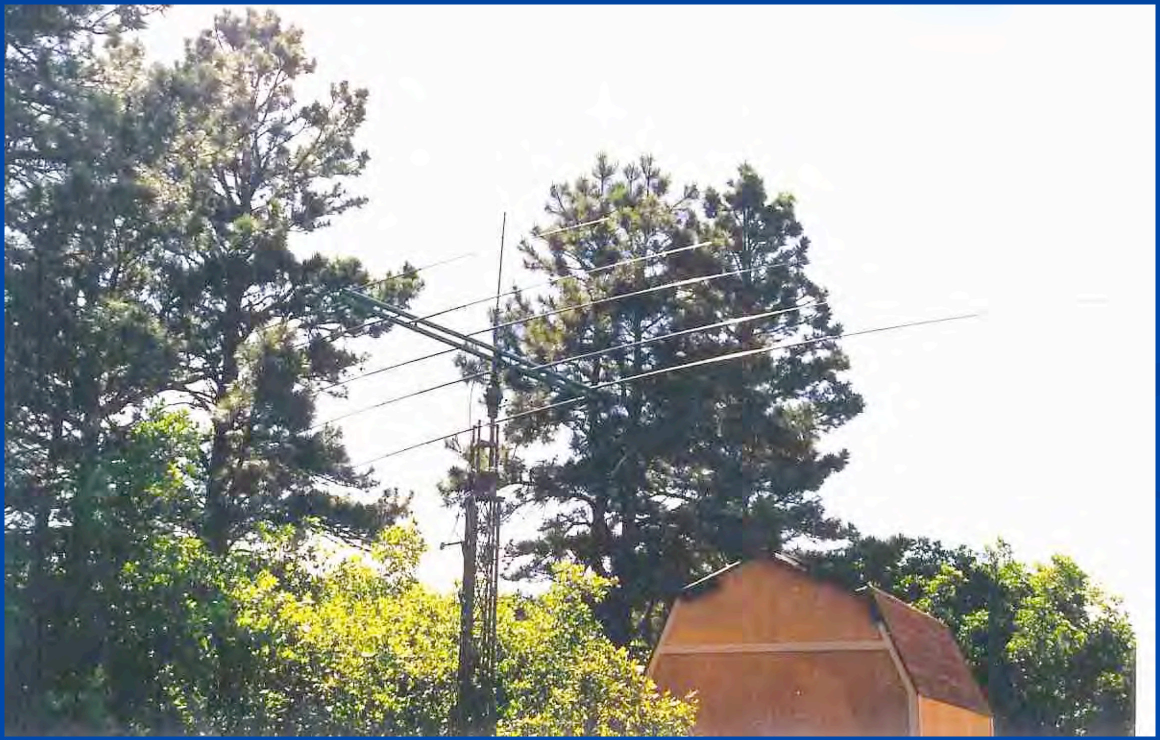
0.5” ├── 0.75” ──┤ 1.0”

Photograph of six blunt aluminum lightning rods, each of which has been struck by lightning.

Photo courtesy C.B. Moore

Direct Strikes

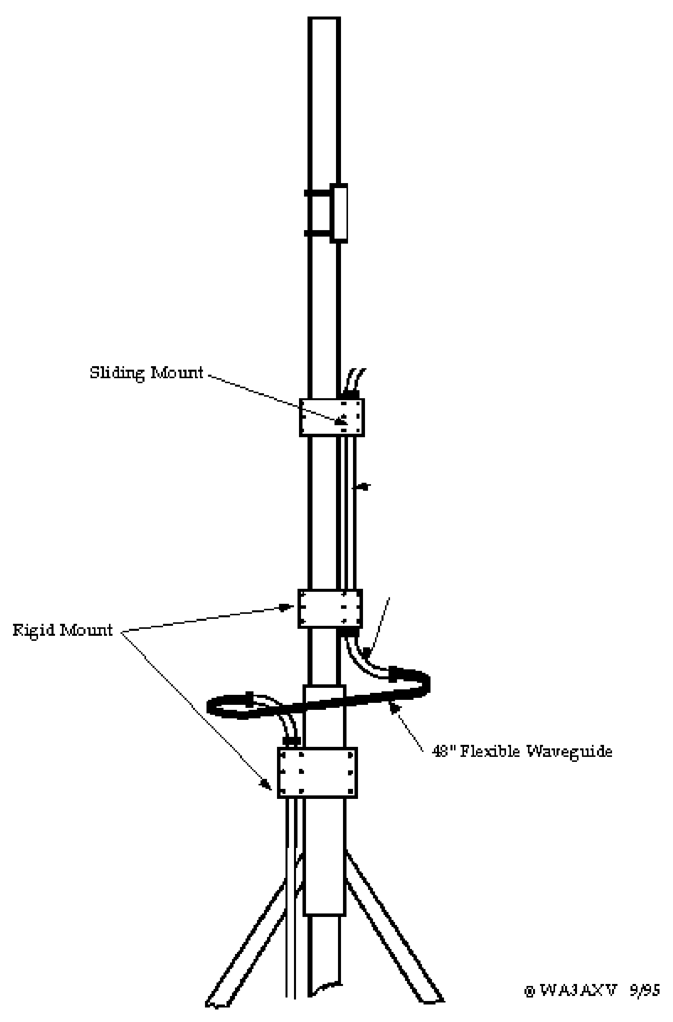
Good bonding is a necessity!
Use clamps — do not solder!



Photos courtesy Bill Otten, KC9CS

Direct Strikes

Couple lightning energy into the tower

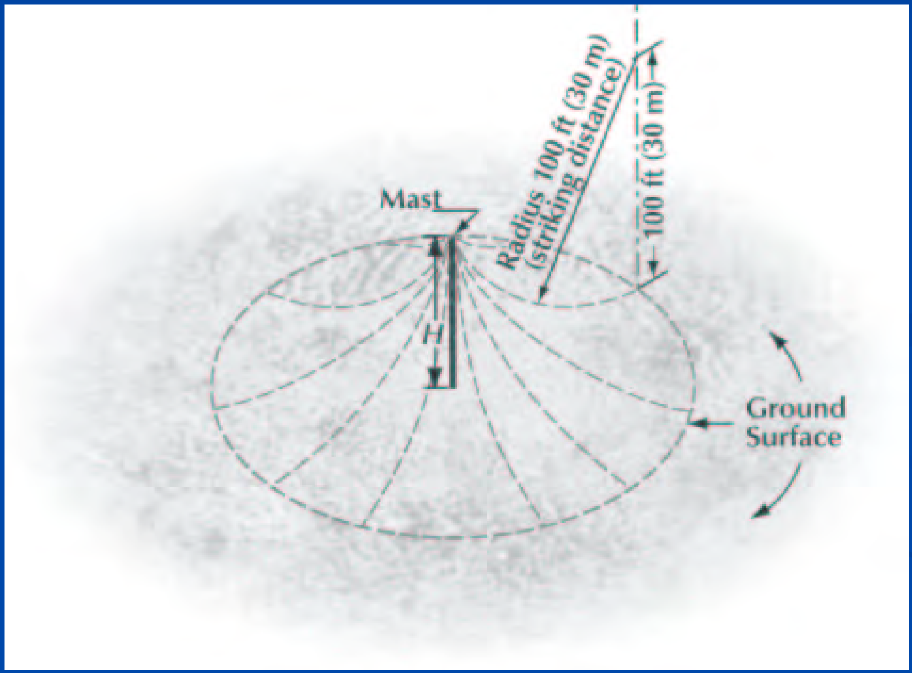


Bond a large wire to the mast and the tower with a flexible loop around the rotor.

Also depends on how your rotor is built.

What about lightning rods for my house?

Use the “striking distance” concept



Zone of protection for a single mast of height H, as determined by the rolling sphere method (from NFPA 780).

What about lightning rods for my house?

What works

- NFPA 780
- Franklin Rods
- Careful installation
- Regular Maintenance
- PolyPhaser info
  (web and books)

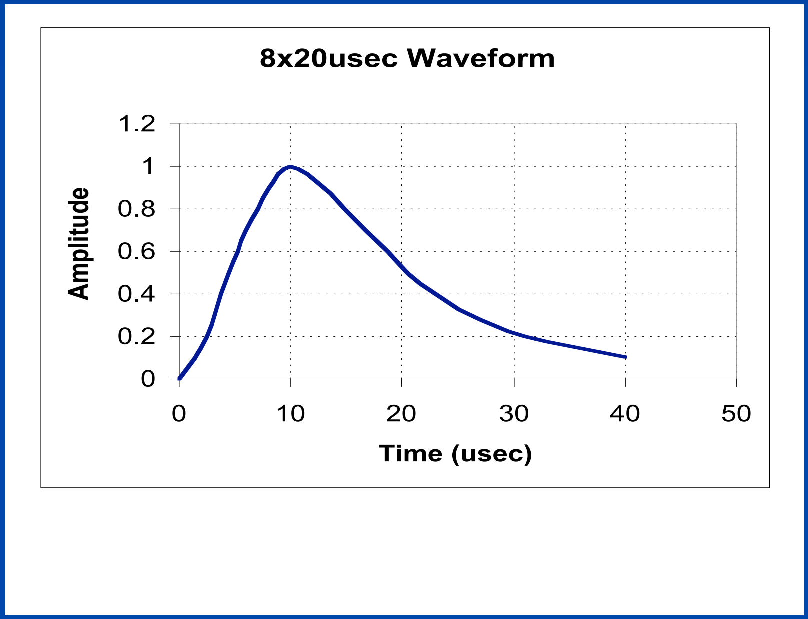
What doesn't work

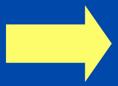
- Lightning "eliminators"
- Lightning "preventers"
- Dissipation Arrays
- Early Streamer Emitters
- Remember Rule #1 !

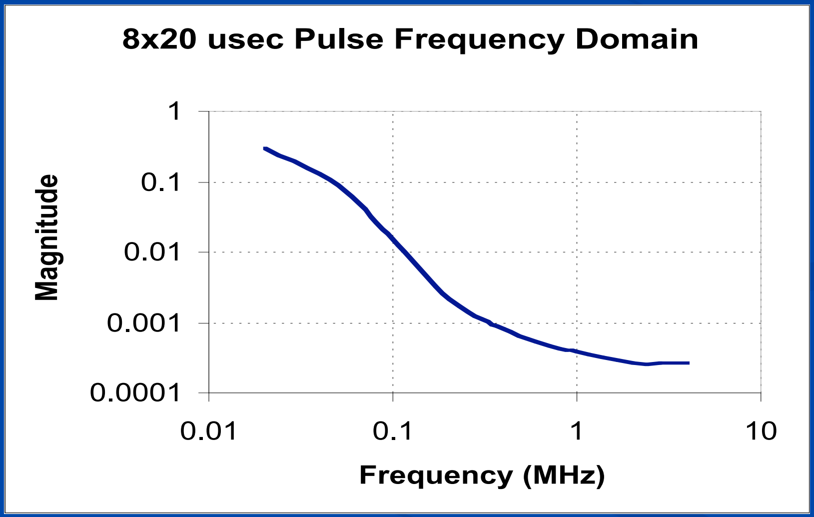
Understanding why …

Electrical Characteristics of Lightning Transients

- Direct strikes are current pulses
  - Lightning streamers from objects on the ground: 100s of amps
  - Return strokes to attached object: 10,000s of amps



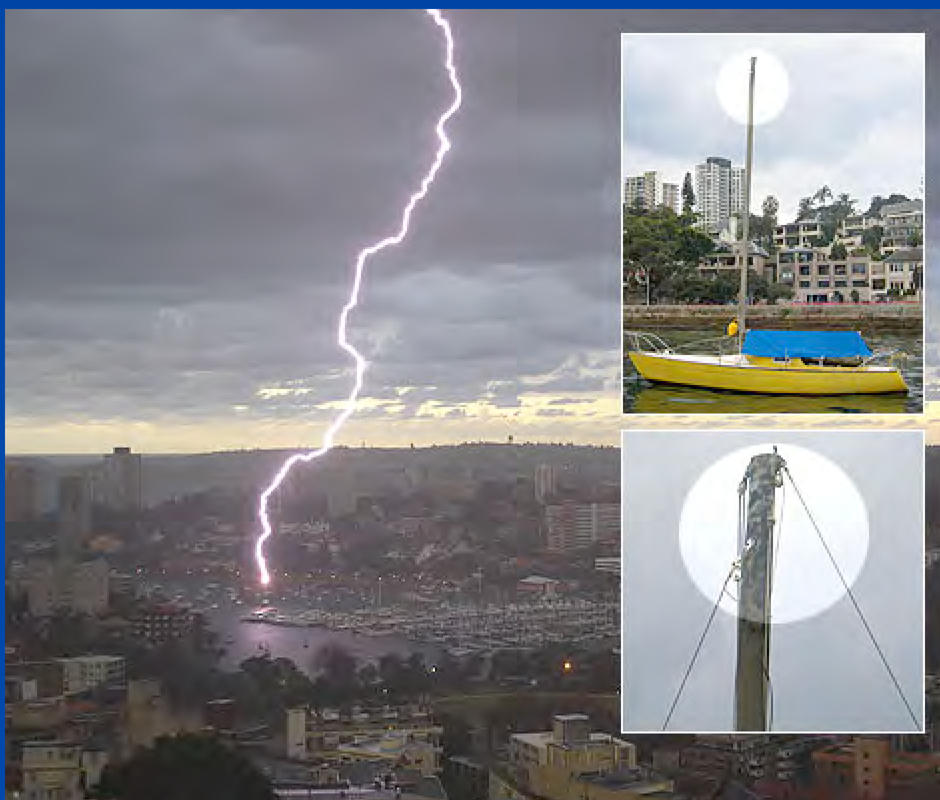




- Typical current pulse shape implies most energy is in lower frequencies

Propagation and Effects of Lightning Transients

- Once a lightning discharge attaches to an object, the resulting current flow tends to be along the **path of least impedance**:
  - Resistance and inductance lead to the development of **high voltages** that can initiate additional current paths via arcing.
  - High current through resistance = extreme **heating**



Lightning strikes mast of boat among tall buildings

Lightning strikes tree and follows roots

Antenna Protection (1)

- Antenna on top of a tower is a **preferred lightning target.**

- Thin wall aluminum tubular antennas subject to destruction by kiloamp level current heating.

- Possible that a **vertical blunt air terminal** mounted above antennas would be preferentially struck vs. antenna elements in corona.

- **“Grounded” antennas** allow significant portion of lightning current to be shunted to earth.
  - Antenna voltage null point at resonance bonded to grounded tower.
  - Inductance seen at feedpoint will develop transient voltage due to current pulse.

- Ungrounded antennas need to **ensure sparkover** to tower
  - Physical air gaps
  - Gas tube arrestors

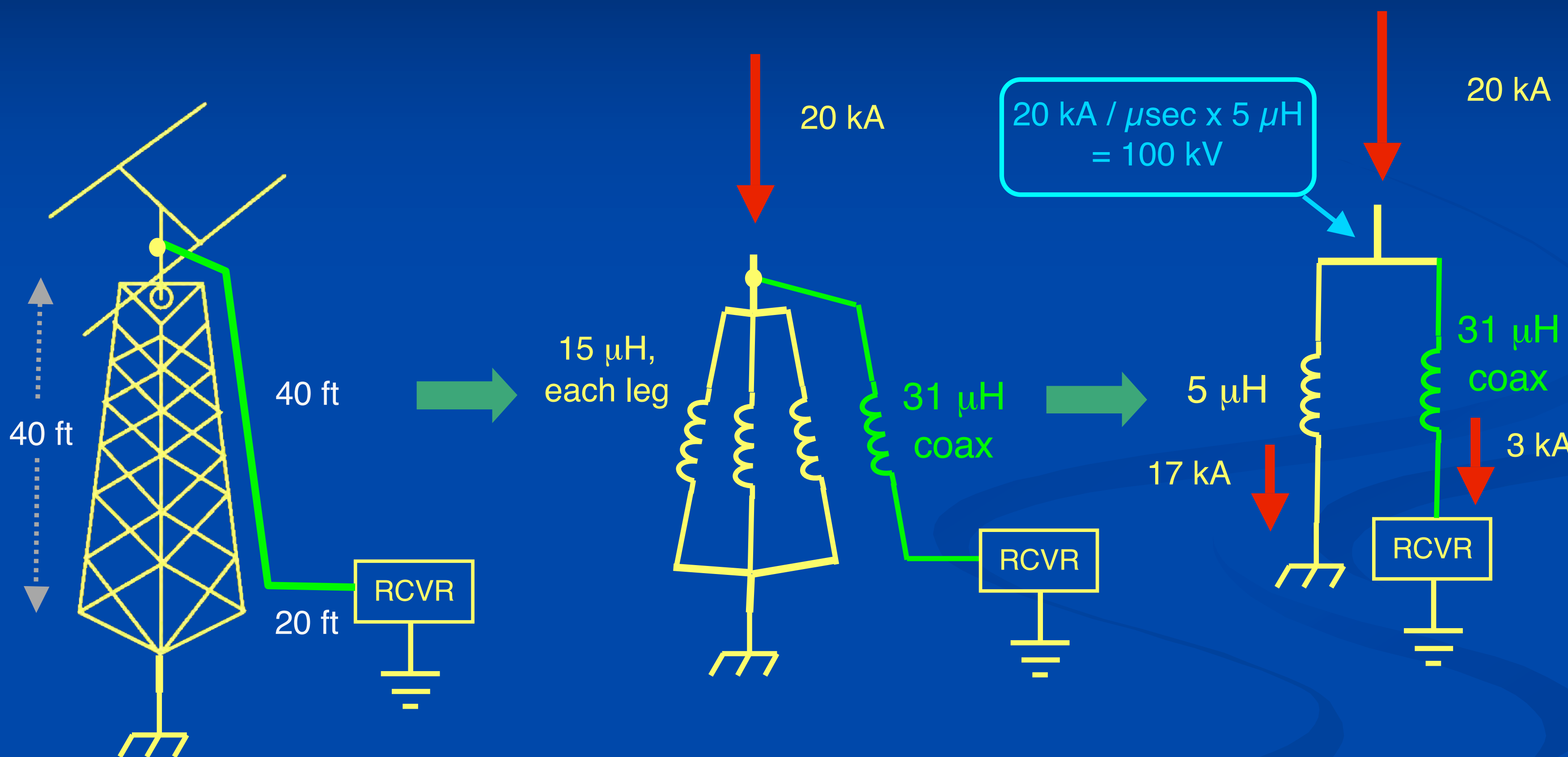
Antenna Protection (2)

- Antenna rotor:
  - Should have **motor shaft and housing bonded** to tower
  - Need on-tower **transient protection** on motor control lines.
- **Tower sections** must be electrically bonded together to ensure conductivity and low inductance to earth
- **Bond coax cable** shield to top and bottom of tower
- On **non-metallic tower**, install copper strap to provide path for lightning current

Illustrations courtesy
Thompson Lightning Protection

Indoor Equipment Protection (1)

How to Survive a 20 kA Strike to your Antenna



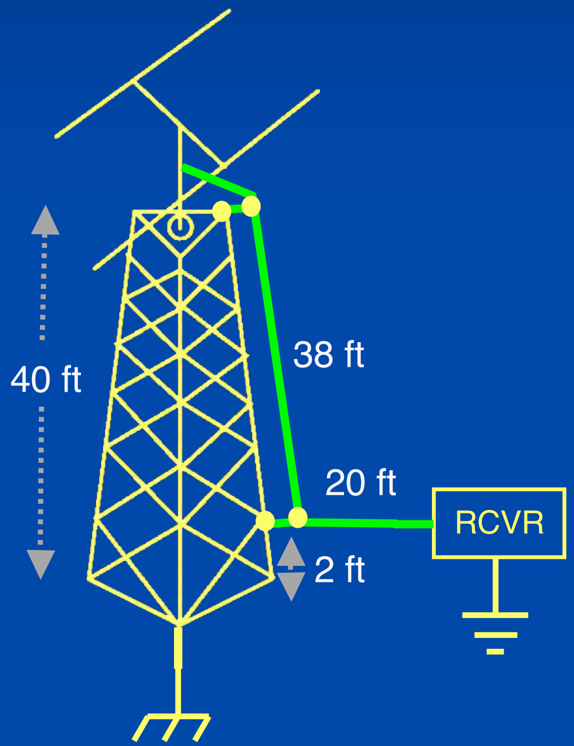
40 ft tower with
1.25" OD steel tubing,
20 ft 1/2" coax run to RCVR

Feedline only connected to antenna; isolated from tower

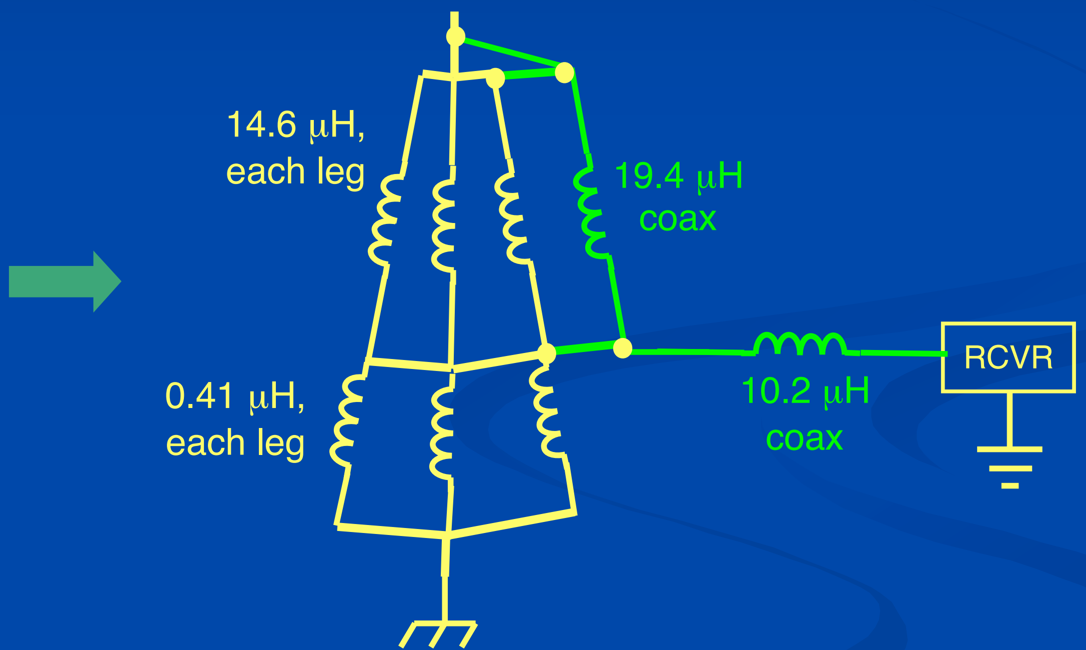
Lightning current elevates tower potential to 100kV and 3 kA heads for receiver

Indoor Equipment Protection (2)

How to Survive a 20 kA Strike to your Antenna



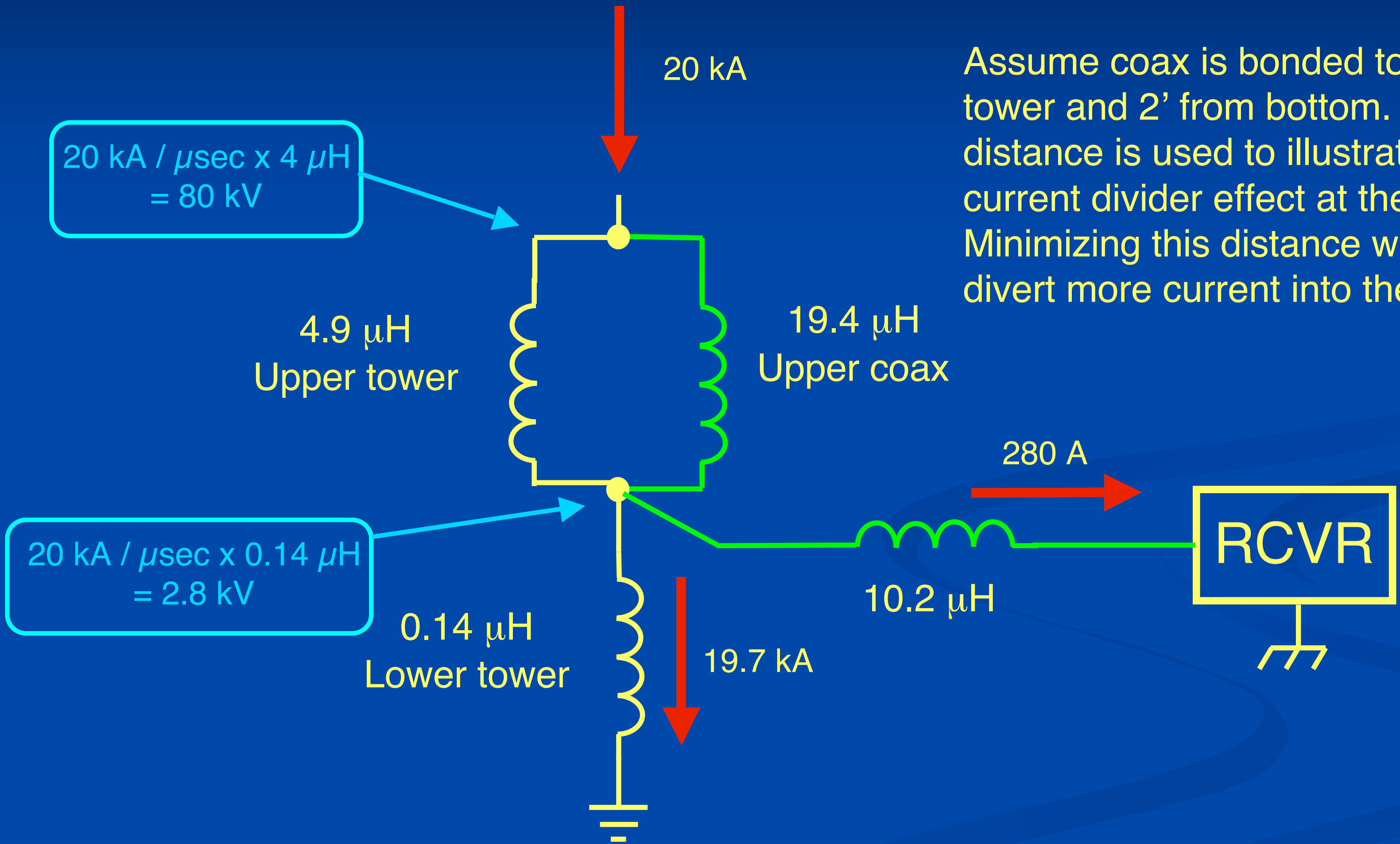
Bond feedline to top and bottom of tower



Equivalent circuit: upper coax in parallel with tower legs

Indoor Equipment Protection (3)

How to Survive a 20 kA Strike to your Antenna

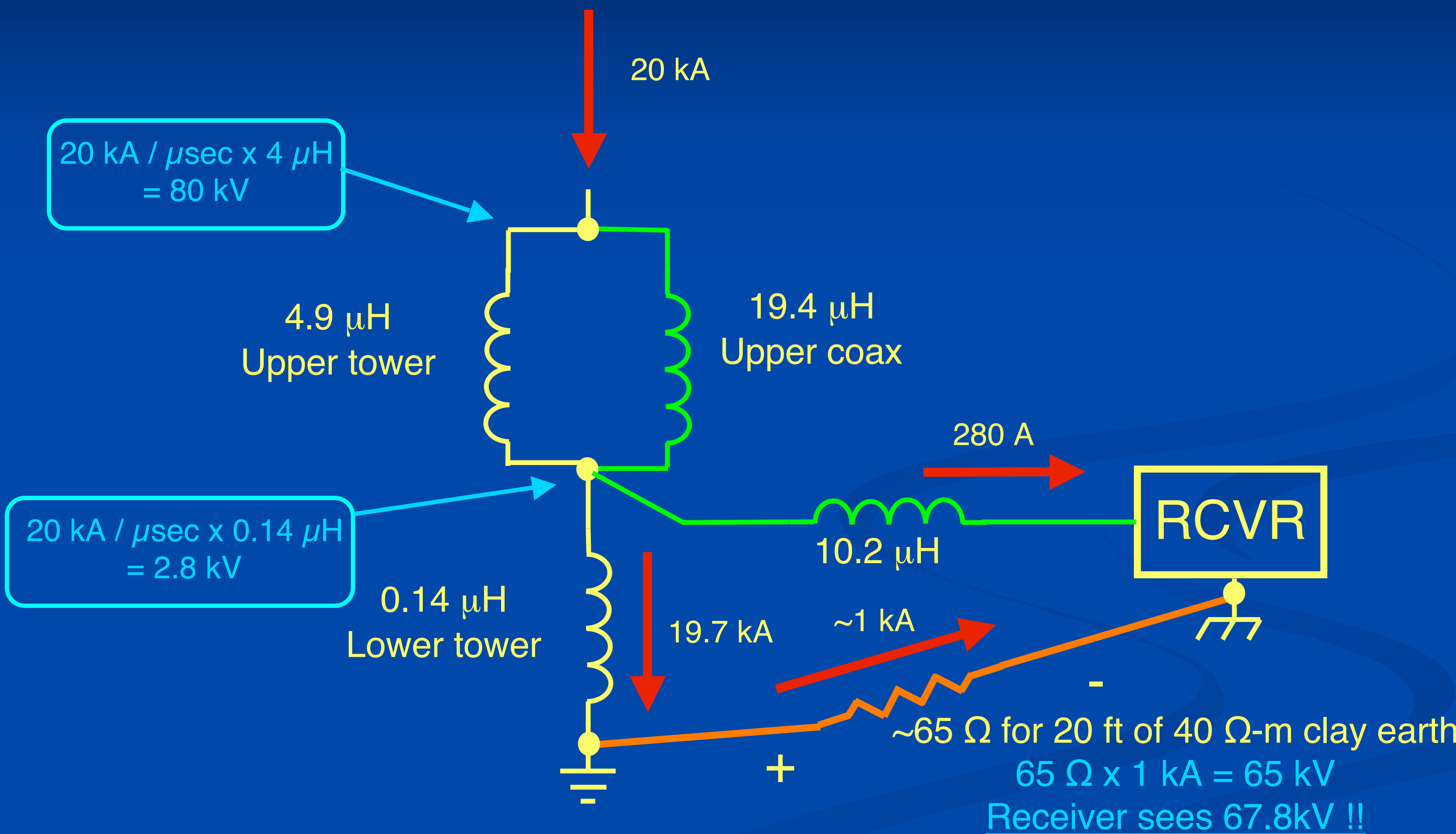


Assume coax is bonded to top of tower and 2' from bottom. This 2' distance is used to illustrate the current divider effect at the ground. Minimizing this distance will help divert more current into the ground.

Bonding the shield of coax near the tower base reduces voltage transient seen by receiver and nearly all lightning current is diverted to earth. Bonding as close to earth as possible is optimum.

Indoor Equipment Protection (4)

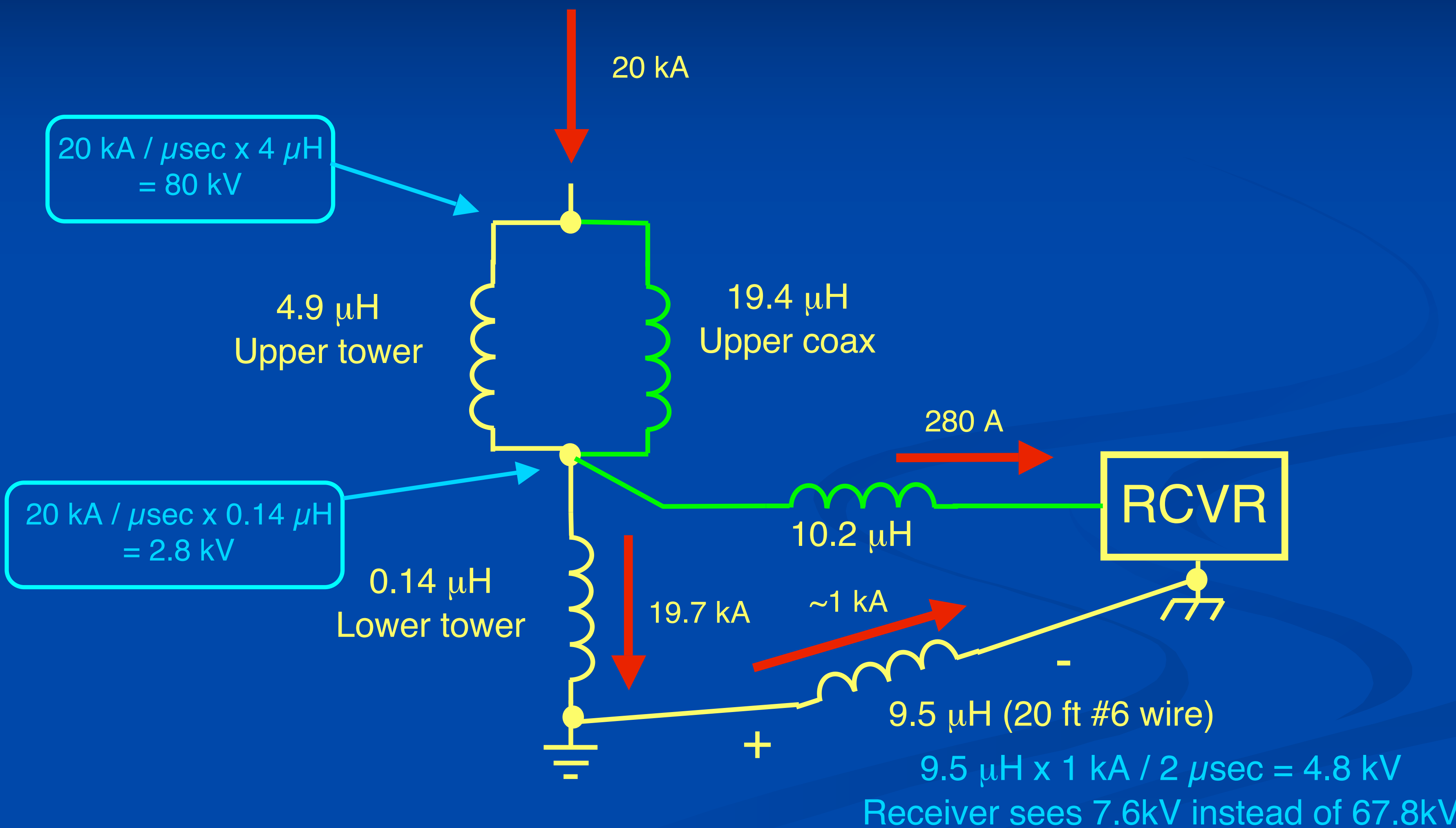
How to Survive a 20 kA Strike to your Antenna



Lightning current spreads out in earth, which develops potential difference between base of tower and receiver local ground

Indoor Equipment Protection (5)

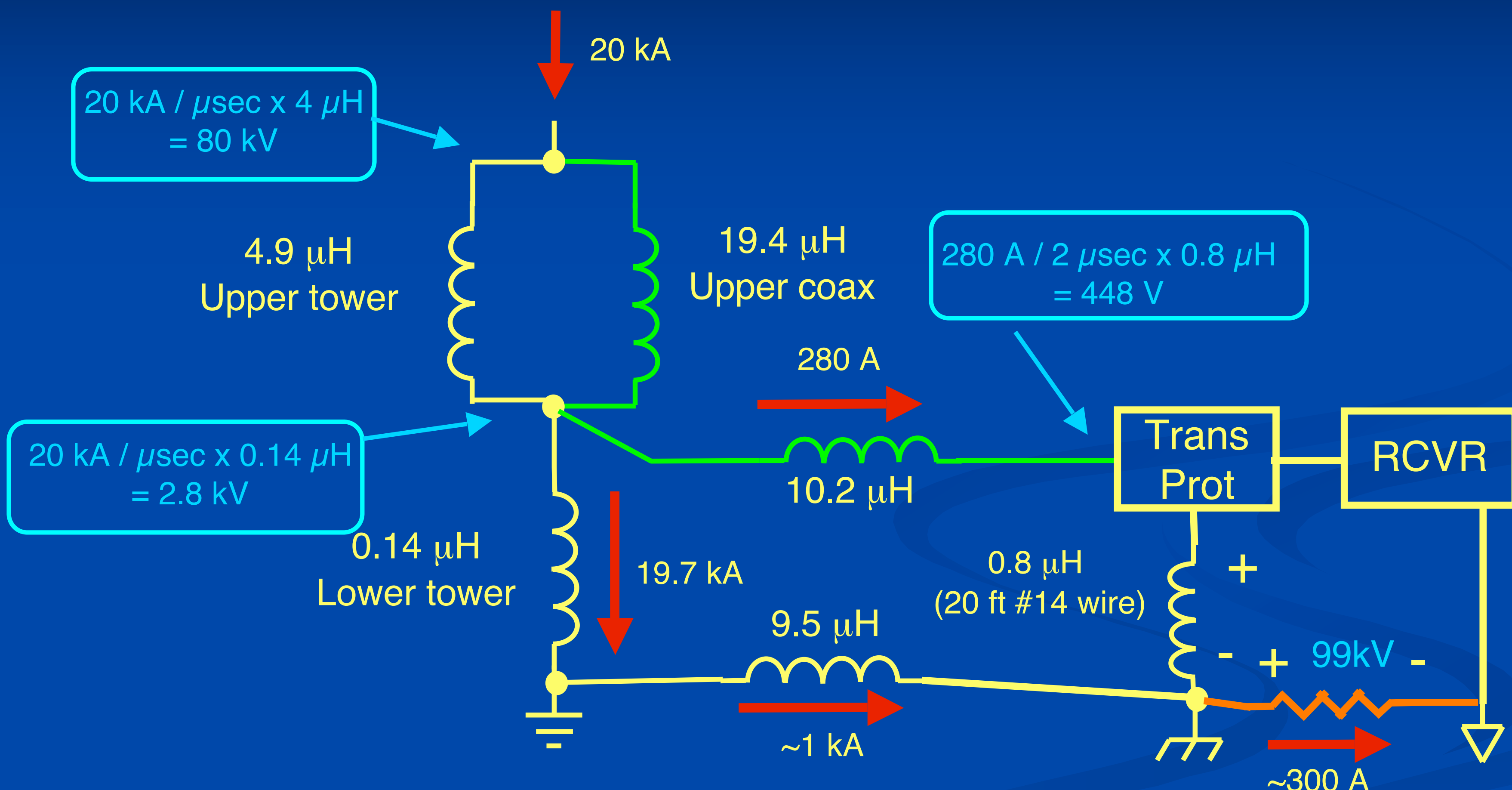
How to Survive a 20 kA Strike to your Antenna



Bonding the receiver local ground to the tower base ground reduces the ground potential difference

Indoor Equipment Protection (6)

How to Survive a 20 kA Strike to your Antenna



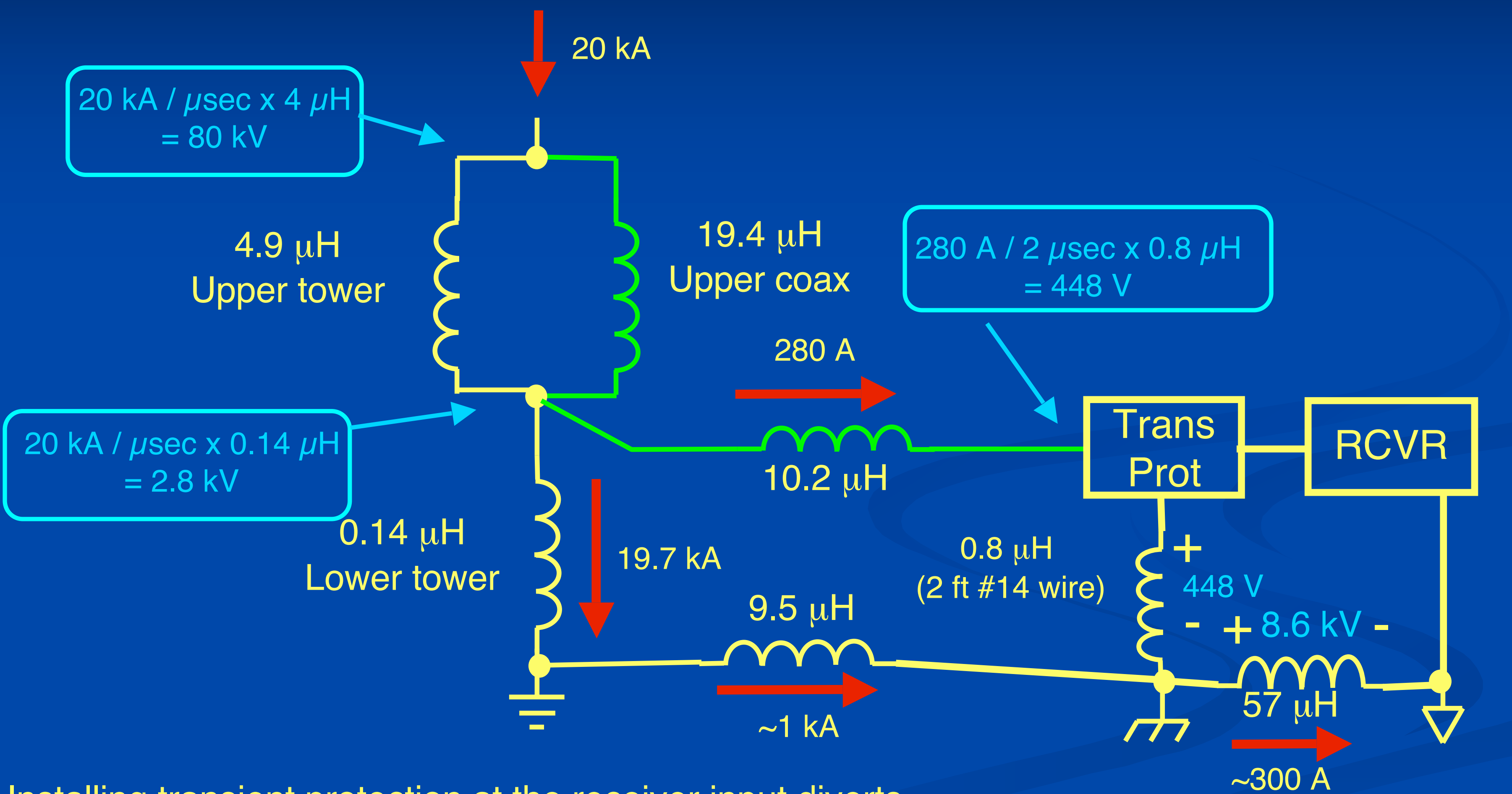
Installing transient protection at the receiver input diverts the lightning current, but a transient voltage is developed across the protector ground lead

~330 Ω for 100 ft of 40 Ω-m clay earth

300 A x 330 Ω = 99kV !!

Indoor Equipment Protection (7)

How to Survive a 20 kA Strike to your Antenna



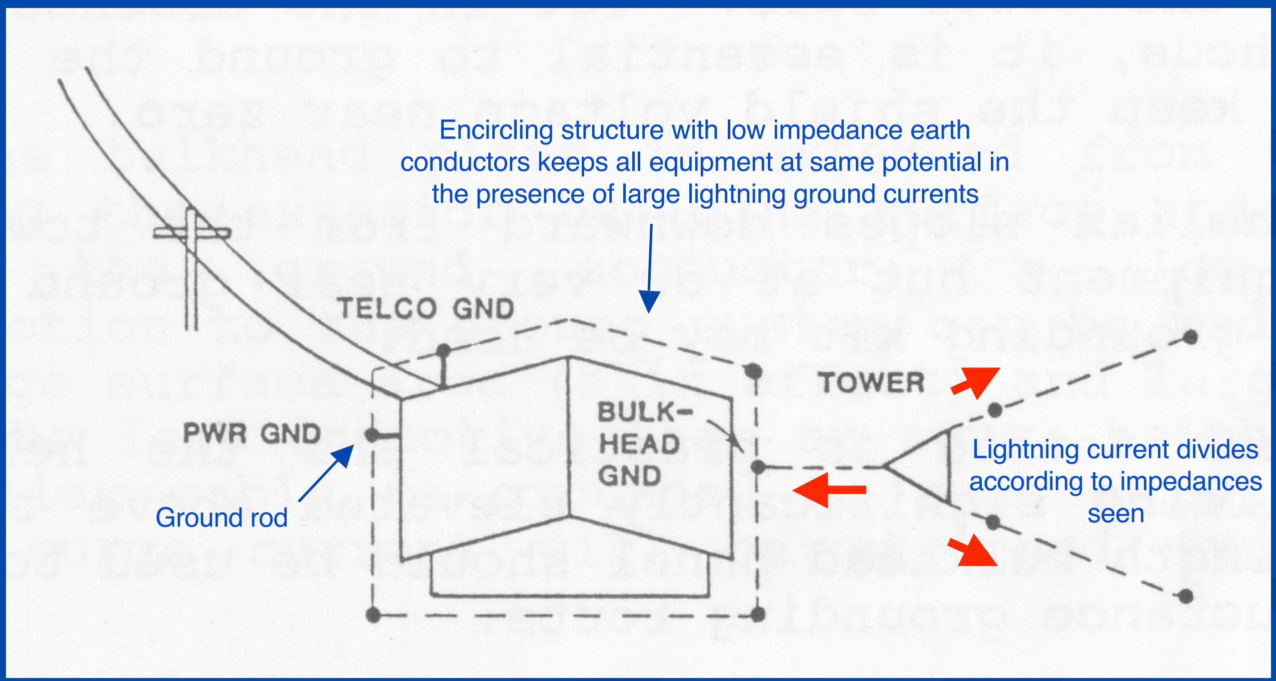
Installing transient protection at the receiver input diverts the lightning current, but a transient voltage is developed across the protector ground lead

~57 μH for 100 ft of #6

300 A / 2 μsec 57 μH = 8.6 kV

Grounding: Earth Terminal (1)

- Grounding plan:
  - Bury conductors to **spread out lightning current**
  - Add “radials” to direct ground lightning current **away from structures, people**
  - **Tie all grounds** together: Tower, Utility, Bldg Perimeter
    - If difficult to complete perimeter ground, at least tie tower and bulkhead to utility grounds



Drawing courtesy PolyPhaser

Grounding: Earth Terminal (2)

- At tower base use **multiple radials**
  - Must double the number of radials to half the earth resistance
  - Spread current away from house
  - 8ft copper-clad rods, spaced ~ 16ft, connected by #4

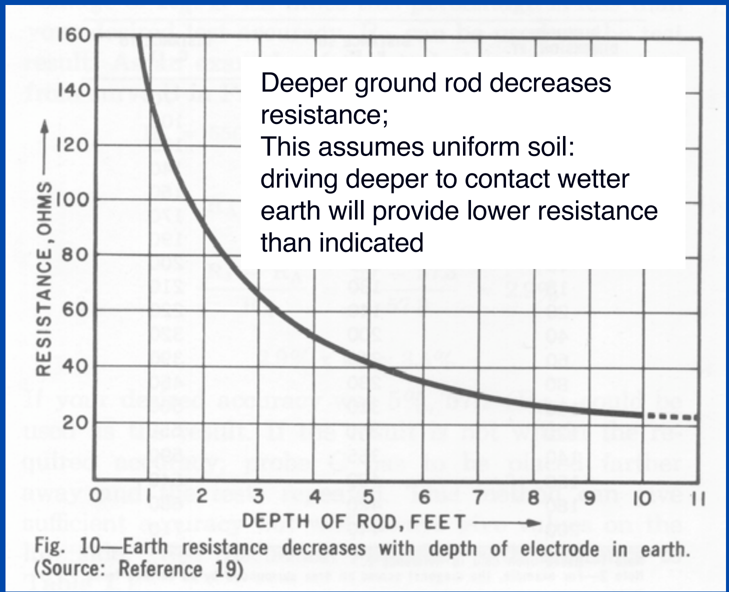
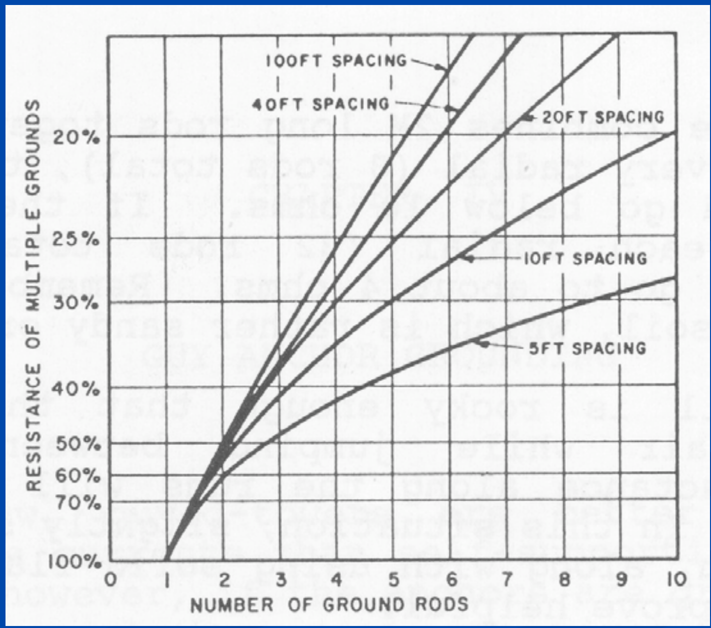


Fig. 10—Earth resistance decreases with depth of electrode in earth. (Source: Reference 19)

Source: OS Peters, US Natl Bur Stds



Source: Copperweld Steel

Grounding: Earth Terminal (3)

- Earth **resistivity varies** with soil type, moisture content
  - Clay is low resistivity
  - Sand and rock are high resistivity

TABLE II—Resistivities of Different Soils*

SOIL	RESISTIVITY OHM-CM AVERAGE	MIN.	MAX.
Fills—ashes, cinders, brine wastes	2,370	590	7,000
Clay, shale, gumbo, loam	4,060	340	16,300
Same—with varying proportions of sand and gravel	15,800	1,020	135,000
Gravel, sand, stones, with little clay or loam	94,000	59,000	458,000

* U. S. Bureau of Standards Technical Report 108

Source: Biddle Instruments

TABLE III—Resistivities of Different Soils**

SOIL	RESISTIVITY, OHM-CM (RANGE)
Surface soils, loam, etc.	100 — 5,000
Clay	200 — 10,000
Sand and gravel	5,000 — 100,000
Surface limestone	10,000 — 1,000,000
Limestones	500 — 400,000
Shales	500 — 10,000
Sandstone	2,000 — 200,000
Granites, basalts, etc.	100,000
Decomposed gneisses	5,000 — 50,000
Slates, etc.	1,000 — 10,000

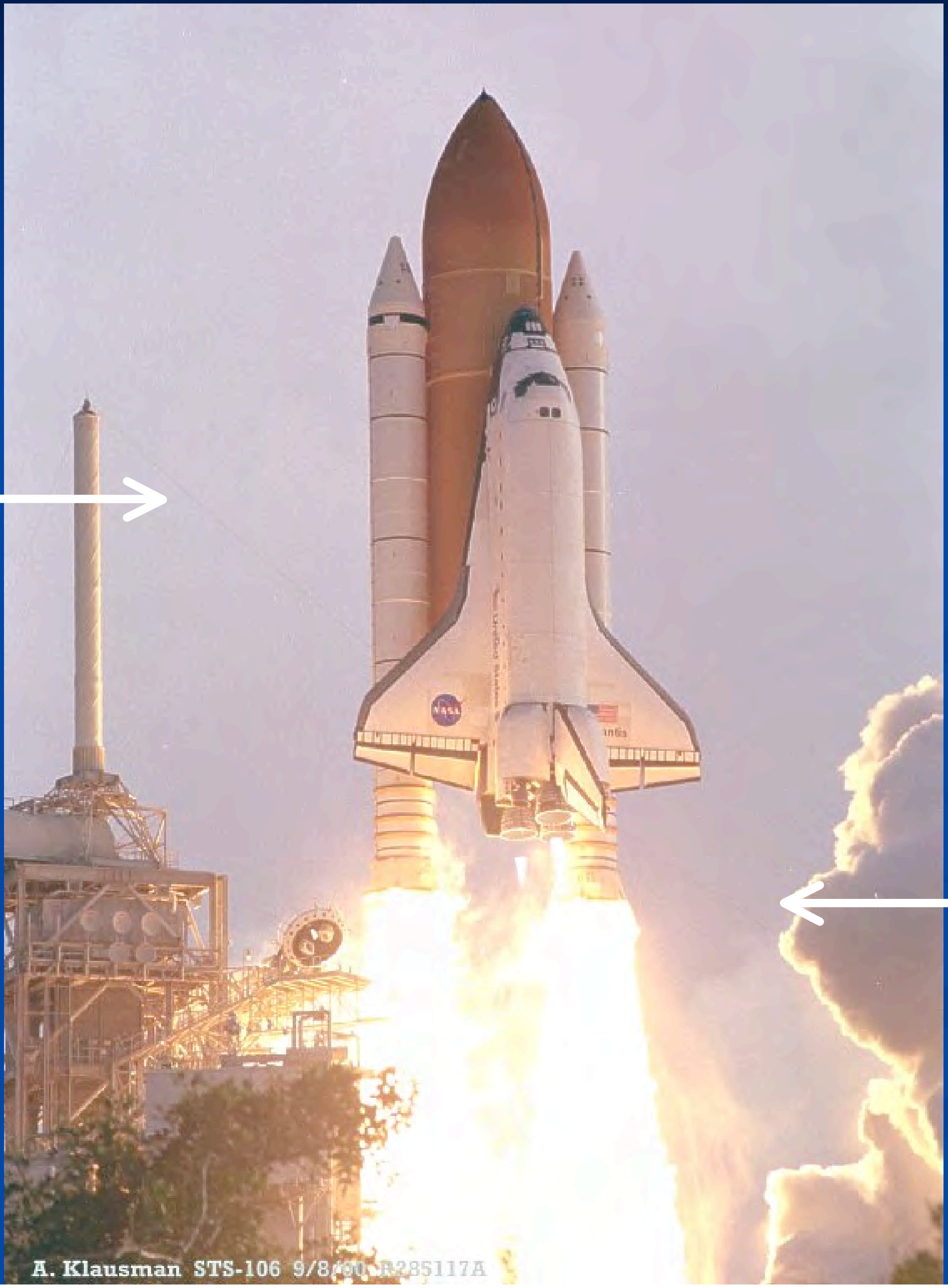
** Evershed & Vignoles Bulletin 245.

Source: Biddle Instruments

What about NASA?

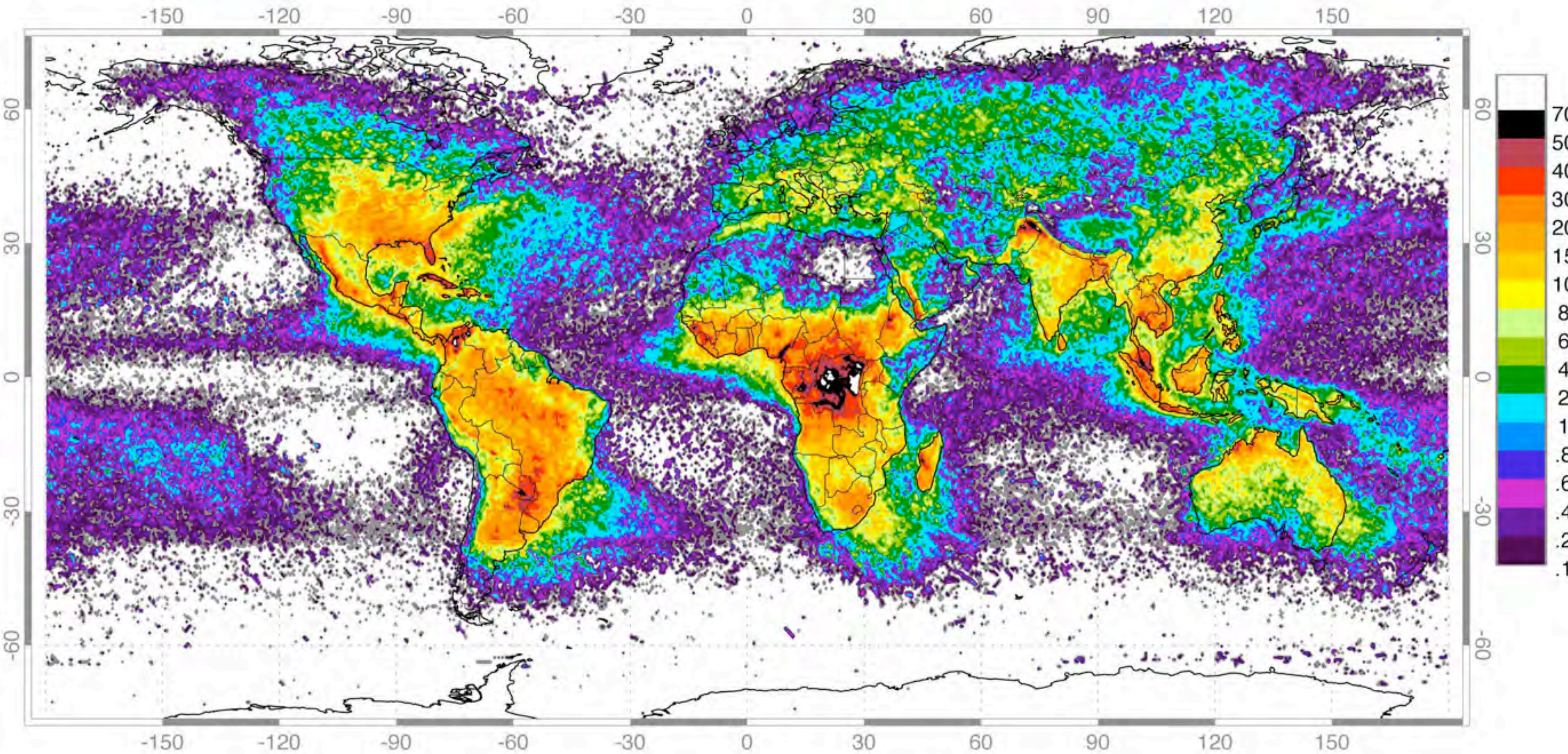
What about NASA?

Catenary Wires



What does lightning do when it reaches the ground?

Lightning Map



High Resolution Full Climatology Annual Flash Rate

Global distribution of lightning April 1995-February 2003 from the combined observations of the NASA OTD (4/95-3/00) and LIS (1/98-2/03) instruments

Data courtesy NASA/MSFC

Resources

ARRL Website:
http://www.arrl.org/tis/info/lightning.html

This presentation:
http://www.arrl-al.org/LtgProt.pdf