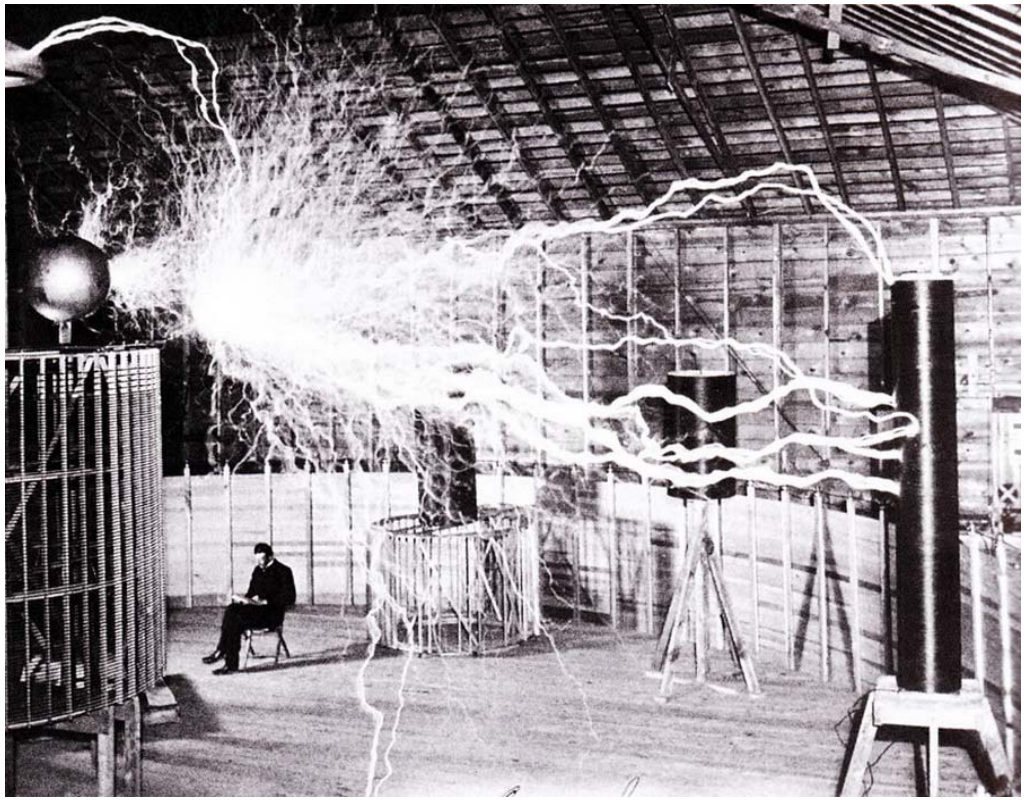
Practical Lightning Mitigation



Jerry Hogan
MBA, BSEE

Director of Engineering,

Solara Technical Sales

Jerry Hogan, MBA, BSEE Director of Eng. Solara Technical Sales

BSEE, University of Colorado MBA, University of Chicago

Texas Instruments, Rockwell International, Siemens,

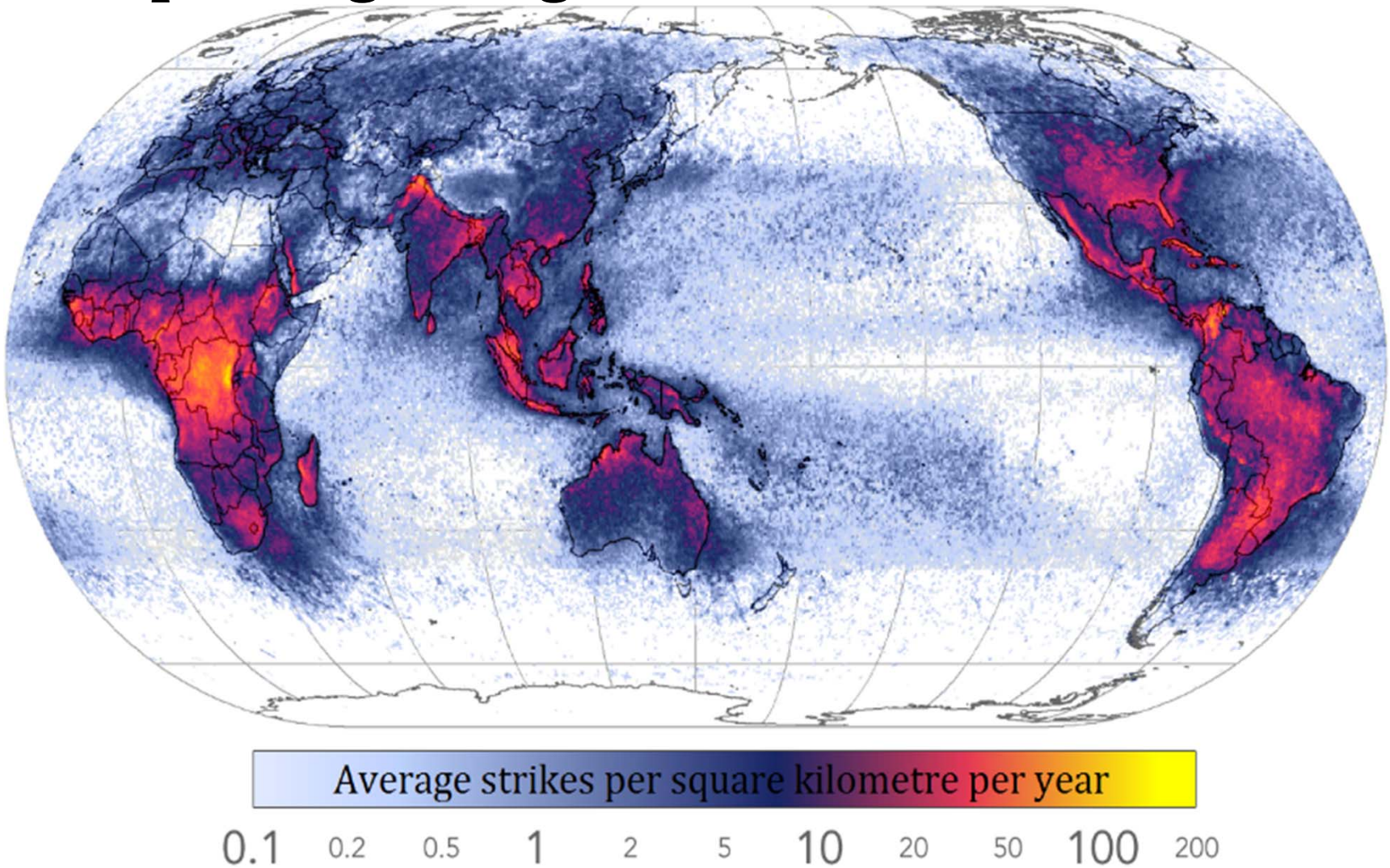
AT&T Bell Labs, Various smaller technical companies

- Definer & designer of power systems & power electronics
- Decades of design experience (am I really that old now?)
- Some level of expertise in outside plant power systems

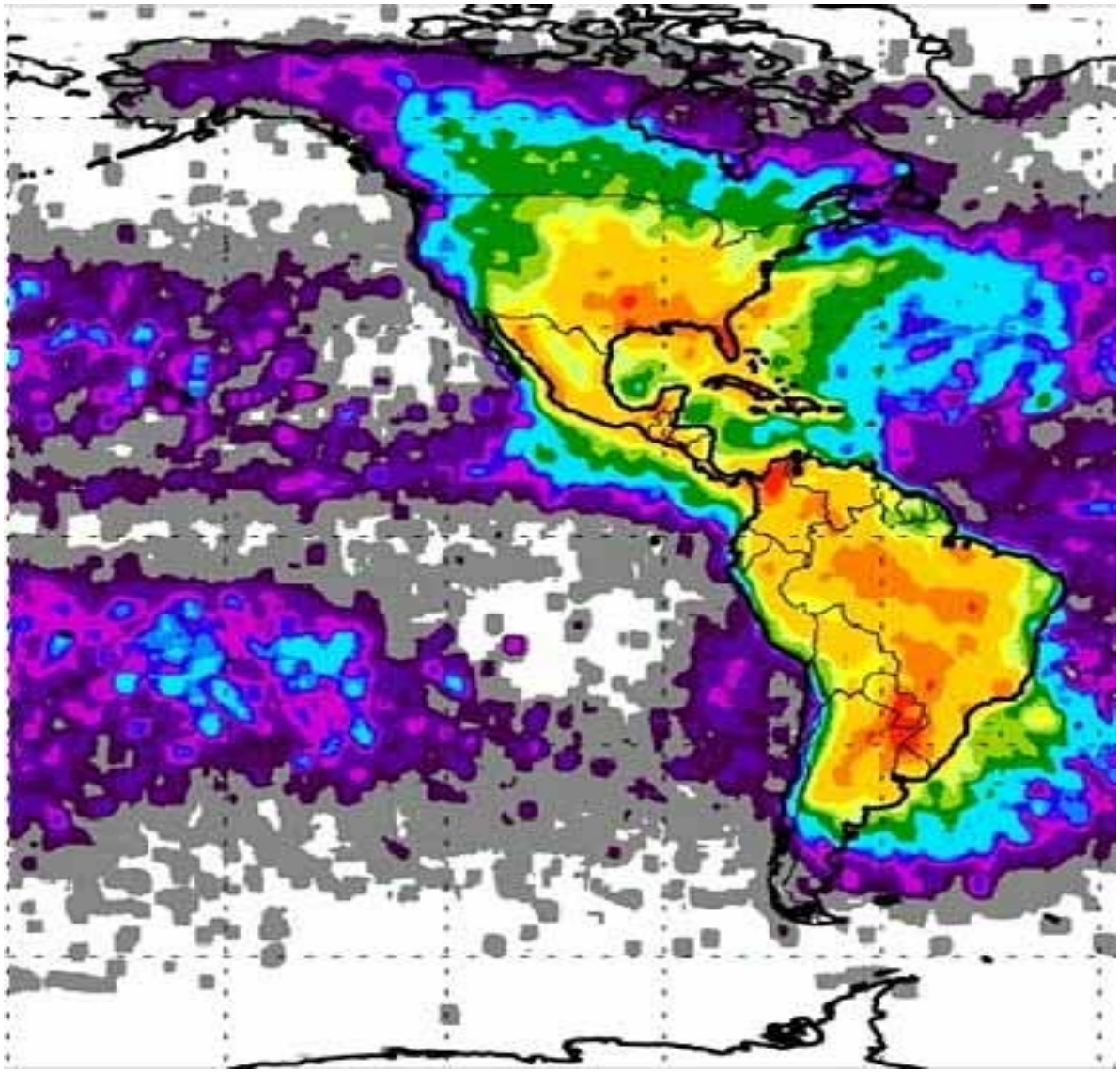
Our Objectives Today

- Understand the energies involved.
- Understand the 4 levels of protection one typically designs to.
- Control where the lightning strikes.
- Control the impedances properly.
- Know where high inductance is helpful and where low inductance is helpful.

Map of Lightning Strikes Around the Globe



Map of Lightning Strikes in Western Hemisphere



The Design Standards

- IEC 62305 series (Design standard in the US)
  - IEC62305-1 Part 1:General Principles
  - IEC62305-2 Part 2:Risk Management
  - IEC62305-3 Part 3:Physical Damage to Structure and Life Hazard
  - IEC62305-4 Part 4:Electrical and Electronic Systems within Structures
  - IEC62305-5 Part 5:Services (This part was not introduced)

- EN 50164 series (in Europe only currently, for components)
  - EN50164-1 Lightning protection components (LPC)– Part 1: Requirements for connection components
  - EN50164-2 Lightning protection components (LPC)– Part 2: Requirements for conductors and earth electrodes
  - EN 50164-3 Lightning protection components (LPC) – Part 3: Requirements for isolating spark gaps
  - EN 50164-4: Lightning Protection Components (LPC) – Part 4: Requirements for conductor fasteners
  - EN 50164-5: Lightning Protection Components (LPC) – Part 5: Requirements for earth electrode inspection housings and earth electrode seals
  - EN 50164-6: Lightning Protection Components (LPC) – Part 6: Requirements for lightning strike counters
  - EN 50164-7: Lightning Protection Components (LPC) – Part 7: Requirements for earthing enhancing compounds

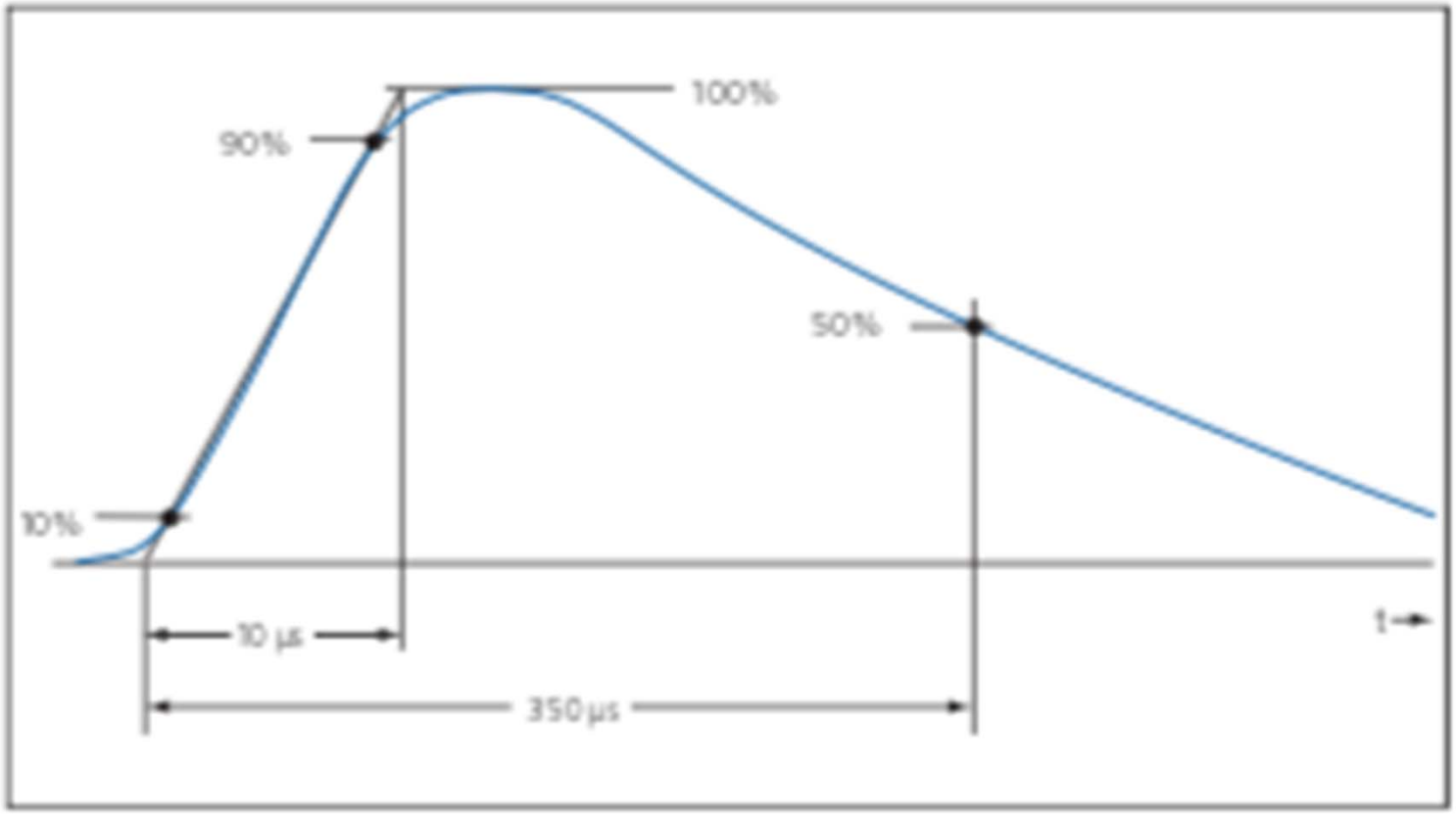
IEC Terminology

Term	Definition
Lightning stroke	Single electrical discharge in a lightning flash to earth. The lightning **flash** may have multiple strokes
Lightning flash	Electrical discharge of atmospheric origin between cloud and earth consisting of one or more strokes
Multiple stroke	A lightning flash where more than one stroke (electrical discharge) occurs
Point of stroke	Point where lightning flash strikes earth/object
Lightning current	Current flowing at point of strike

Theory of Lightning

- The Thundercloud
  - The cloud needs to be 3 to 4 km deep. The taller the cloud, the more frequent the lightning.
  - Approximately 90% of all lightning flashes are cloud-to-cloud with the other 10% being cloud-to-ground flashes.
- Mechanics of the Lightning Strike
  - Ionized channel (low impedance path)
  - Up to 16 strokes have been observed using the one channel. These multiple strokes within the one lightning flash are sometimes referred to as re-strikes.

Theory of Lightning



Lightning, a LOT of energy per stroke:

"An individual bolt can pack several hundred million volts at 10,000 amperes, one trillion watts, briefly burning up more electrical power than is being used in the entire United States. Monsters of one billion volts and over 100,000 amperes are not unknown."

The 4 Levels of Lightning Protection

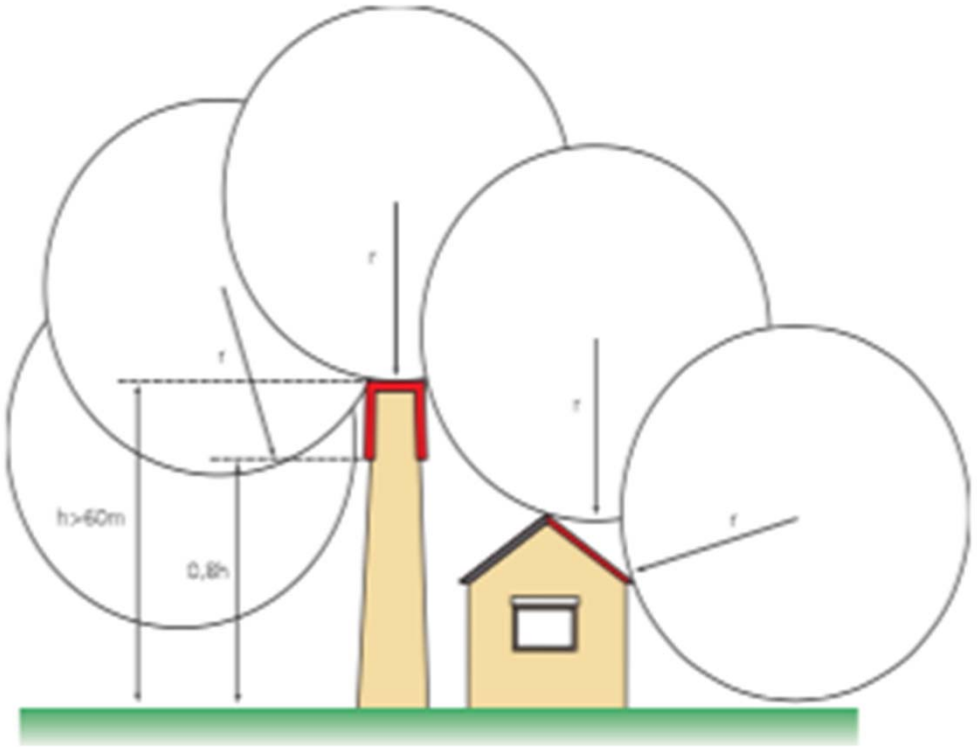
- In the IEC 62305 series, four lightning protection levels are introduced.
- LPL I offers the highest protection level (greatest level of protection), with LPL IV offering the lowest level of protection.

	LPL I	LPL II	LPL III	LPL IV
Maximum peak current (kA 10/350 µs)	200	150	100	100
Probability current is greater (%)	1	2	3	3

Standard Design Methods Used

- Rolling sphere – used in this presentation.
- Mesh method
- Protection angle method

Lightning Protection Zones



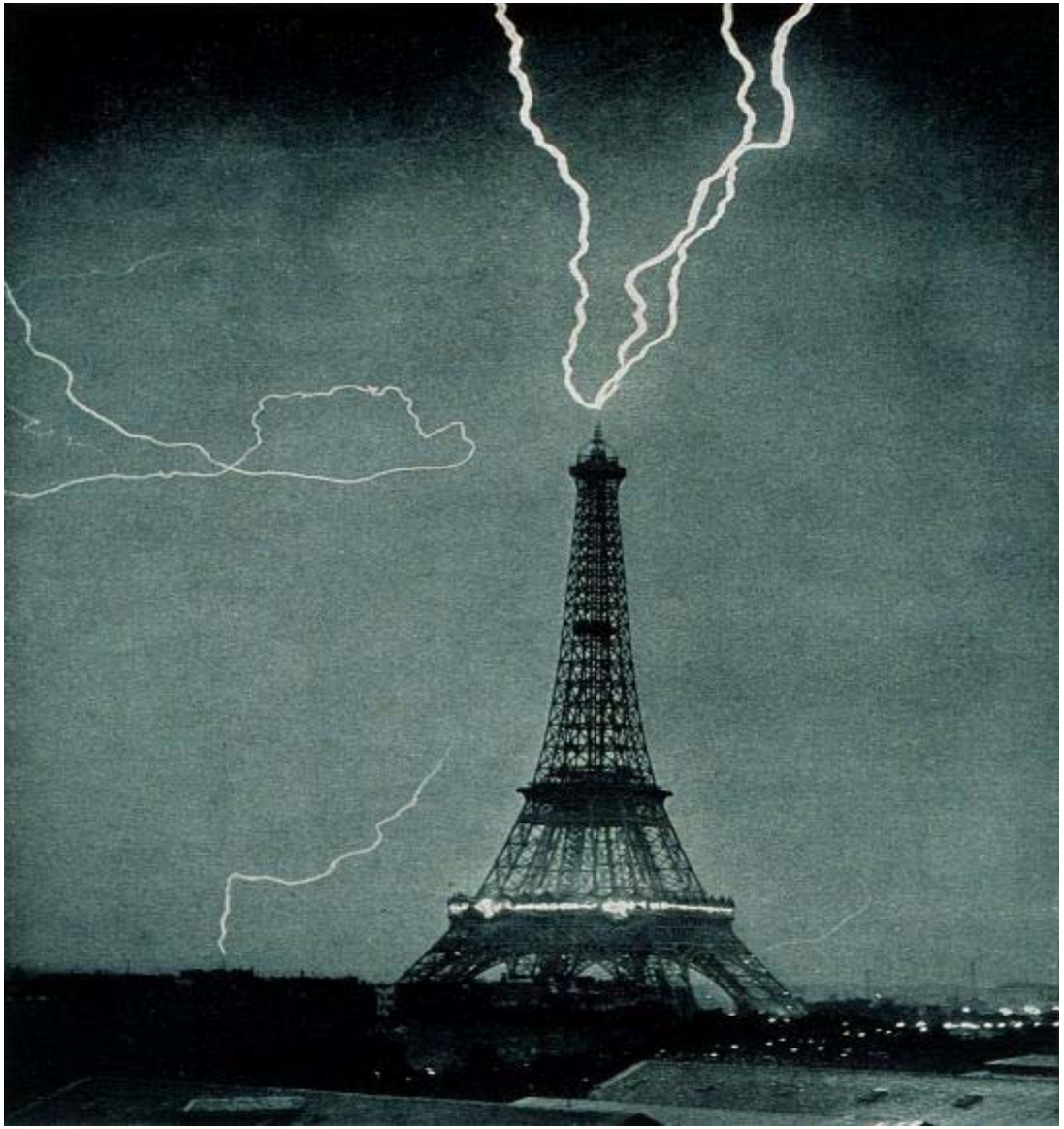
Lightning Protection Zones

	LPL I	LPL II	LPL III	LPL IV
Minimum current (kA)	3	5	10	16
Probability current is greater than minimum (%)	99	97	91	84
Rolling sphere radius (m)	20	30	45	60

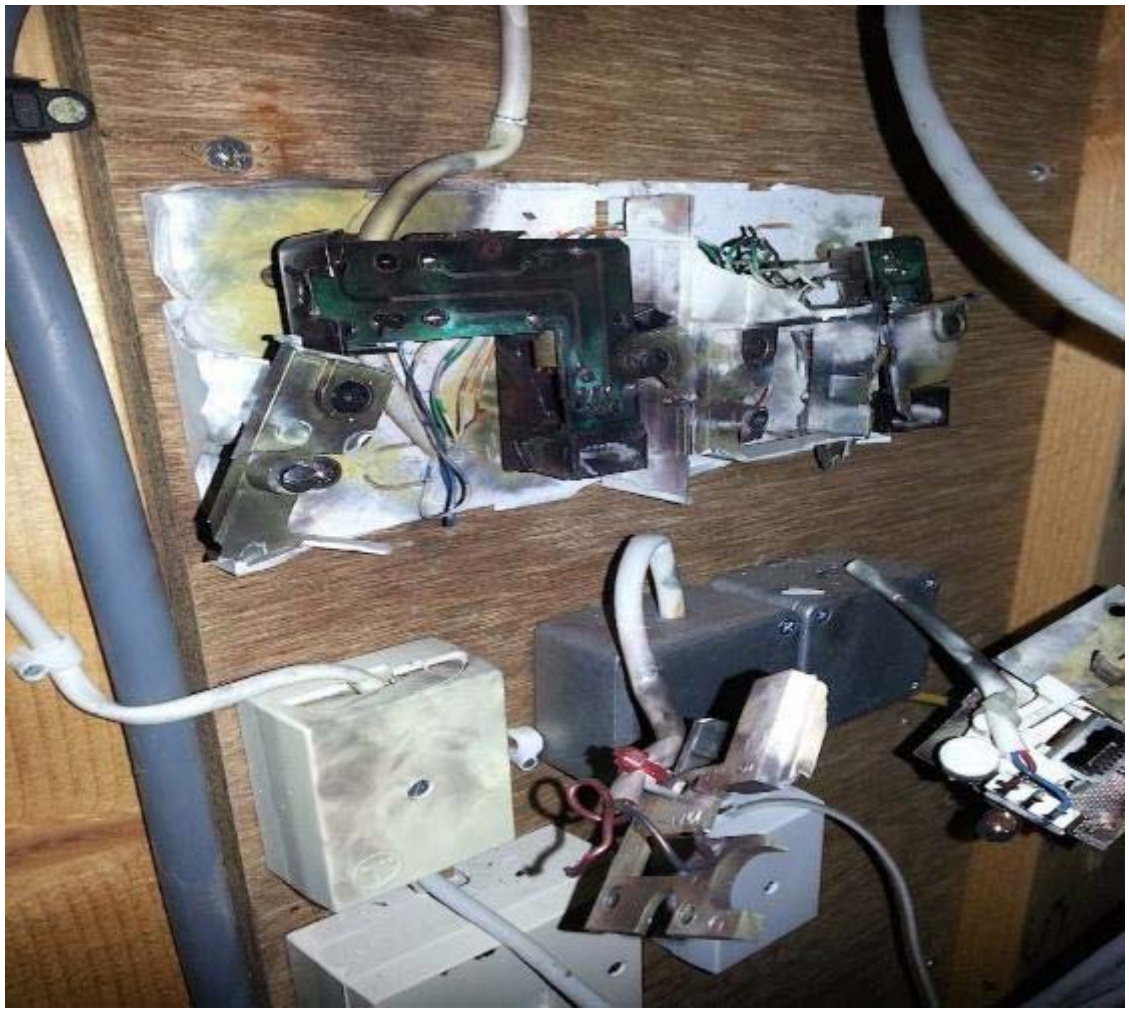
The Problem: Lightning

- We erect ”towers” – cell towers, microwave towers, water towers – whatever.
- And guess what? Shock of shocks (pun intended), they become lightning rods!

So,
Lightning is going to hit our towers



Damage



System Concepts to Consider

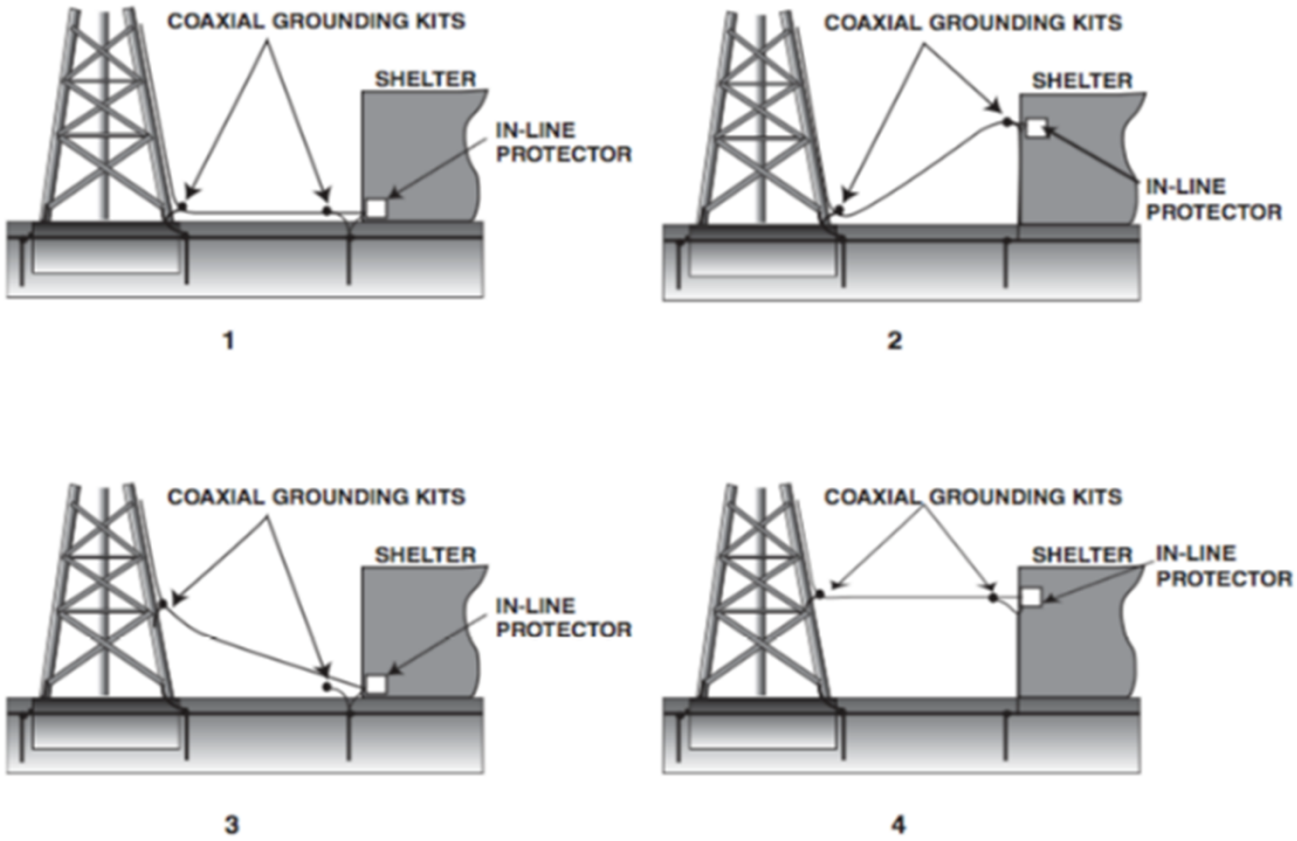
- Use rolling sphere to place lightning rods on tower & building, to the level of protection desired.

- Size conductors for maximum current per the sphere size. Round conductors that have higher inductance should be used here. It will limit the peak current as well as lower the voltage seen at the coaxial ground kits.

- Transition from high inductance to low inductance where your coaxial grounding kits are placed. We are building an inductive divider.

- Get the energy down to the soil. Use low inductance conductors in the soil.

Cable paths make a *HUGE* difference!



If the soil is a perfect ground, then reducing the distance from coax grounding kits to the soil-ground at the tower is the key!

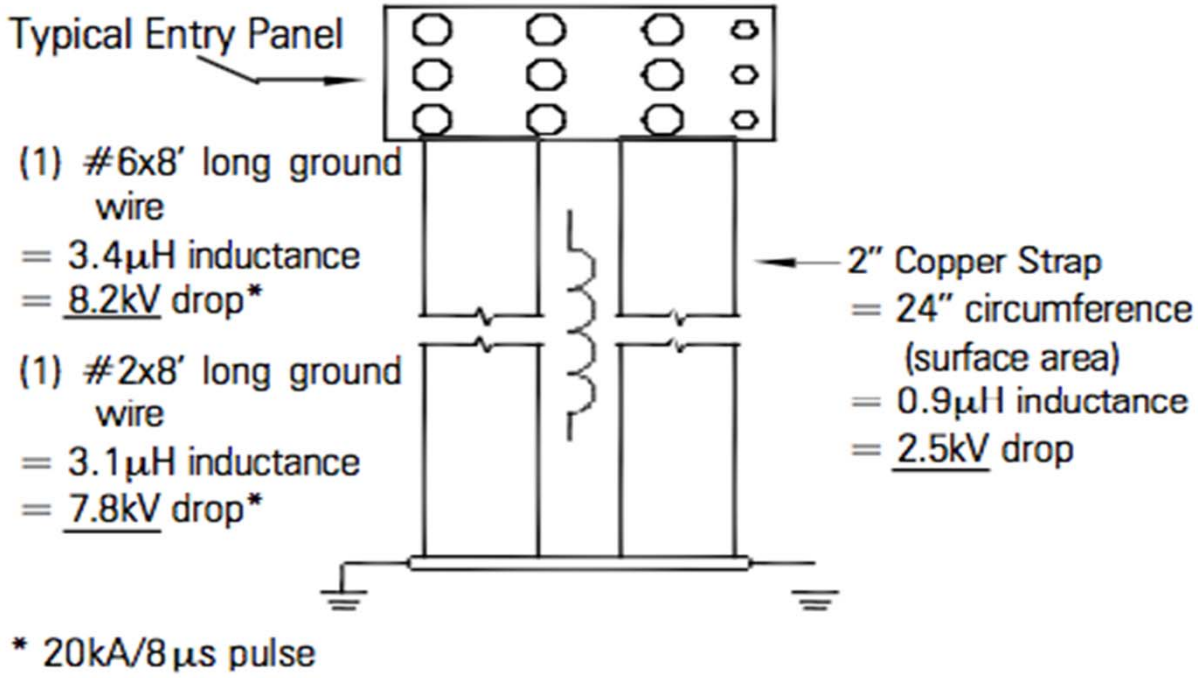
What can we do to reduce, or even eliminate, damage to our electronics?

- **GOAL:** Keep as much of the energy *outside* the building/hut/enclosure as practical/possible and AWAY from the electronics!
- How? Reduce Inductance
  - Lightning really takes the path of least inductance – not the path of least resistance.
  - Let's first assume that the soil is a perfect ground.
  - Let's assume the lighting only hits the lightning rods
  - If we can get the energy down to the soil, instead of into the electronics, everything will work out fine. (This is mostly true)

Two very different Entry Panels

$ $$$

Entry Panel Inductance:



1,000V of potential/one foot of round conductor above ground.

Copper strap? 300V/foot for 2" width copper strap. 3.3X better.

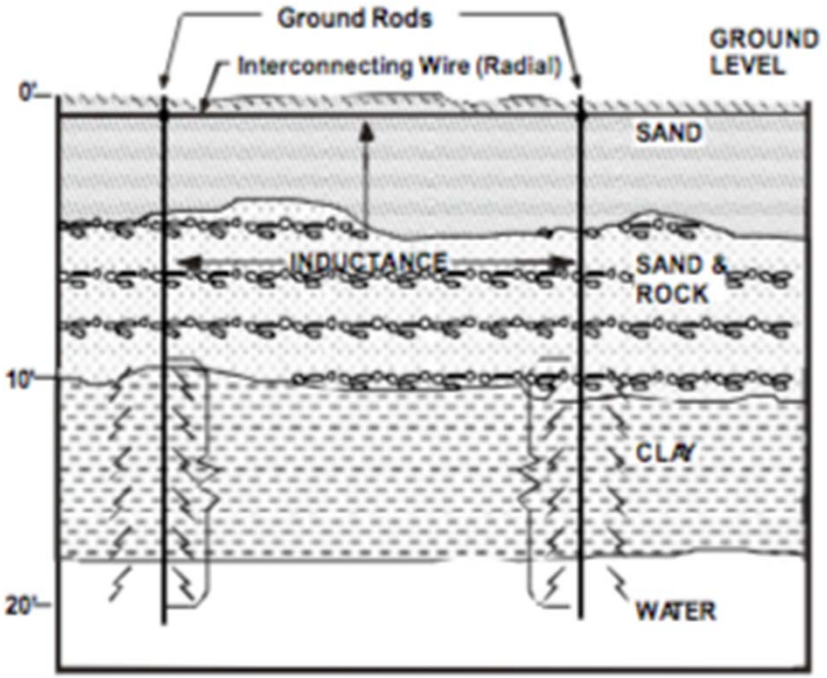
Voltages @ Entry Panel (20kA, 8uS pulse)

6,000V for 6 feet

1800V/6 conductors = 300V for 6’ or 1/20th .

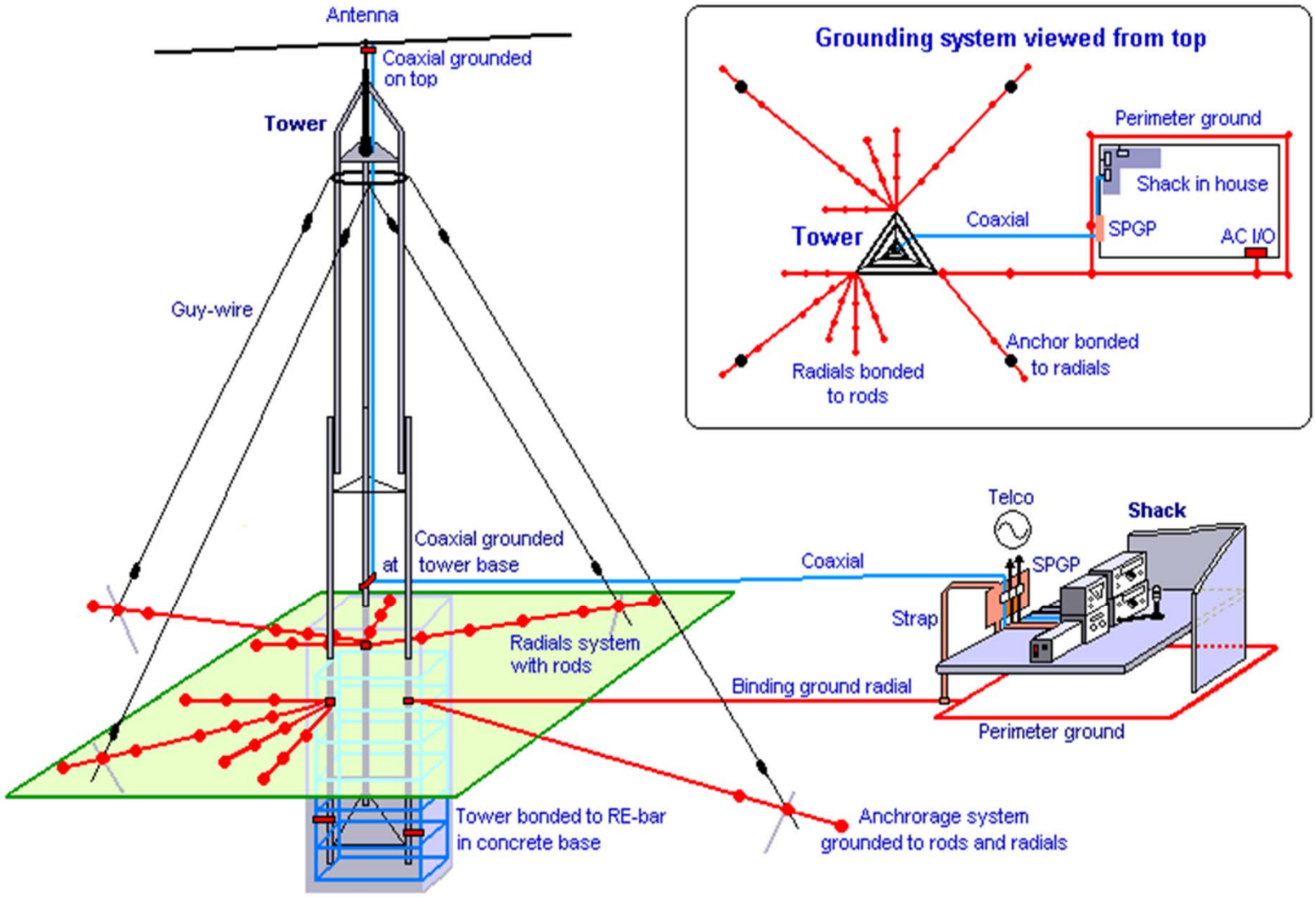
(Again, assume for now that the soil is a perfect ground.)

But Soil is not a perfect ground. Untreated soil is a very poor conductor with high inductance.

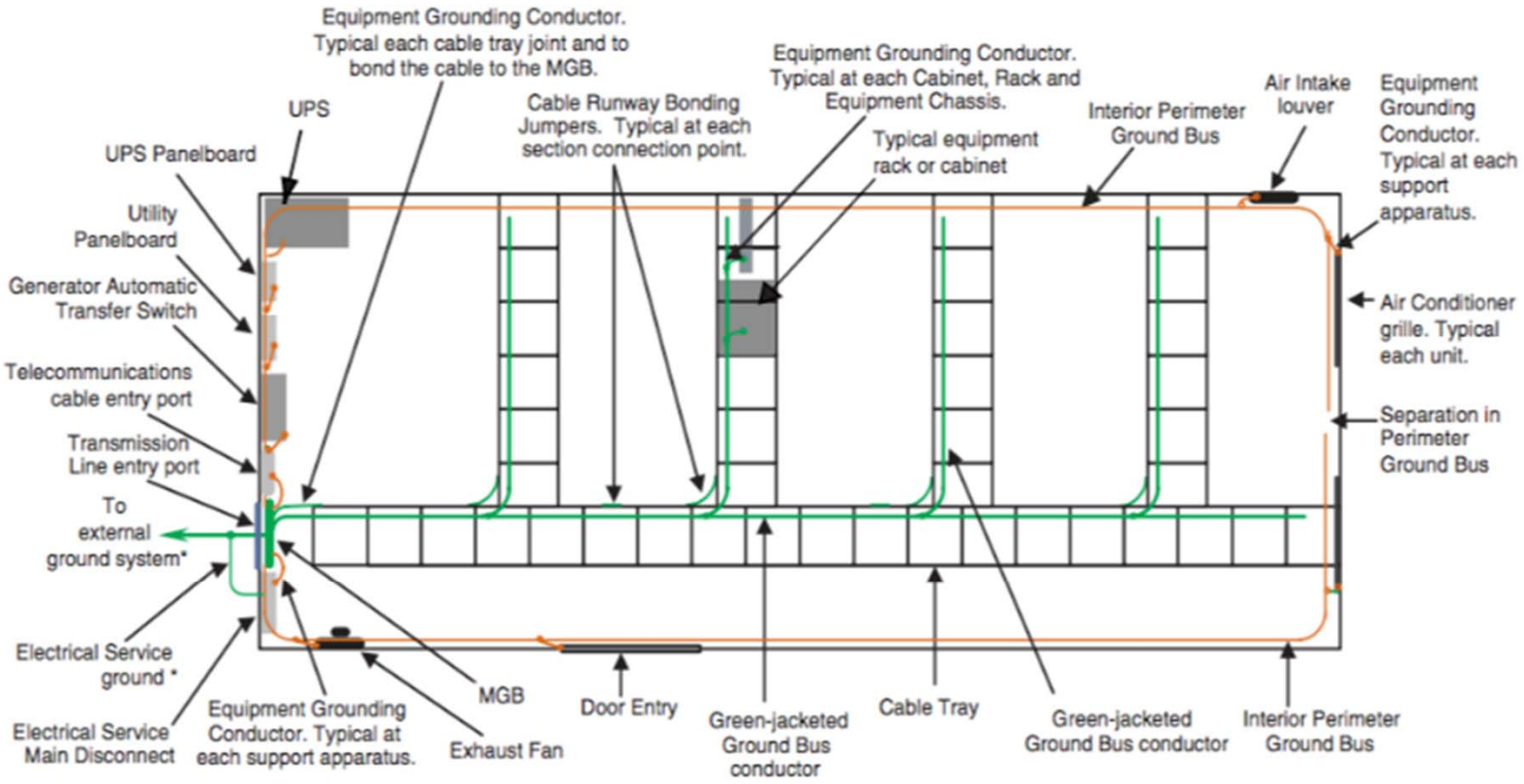


Now this is a low inductance ground!

The Complete Site

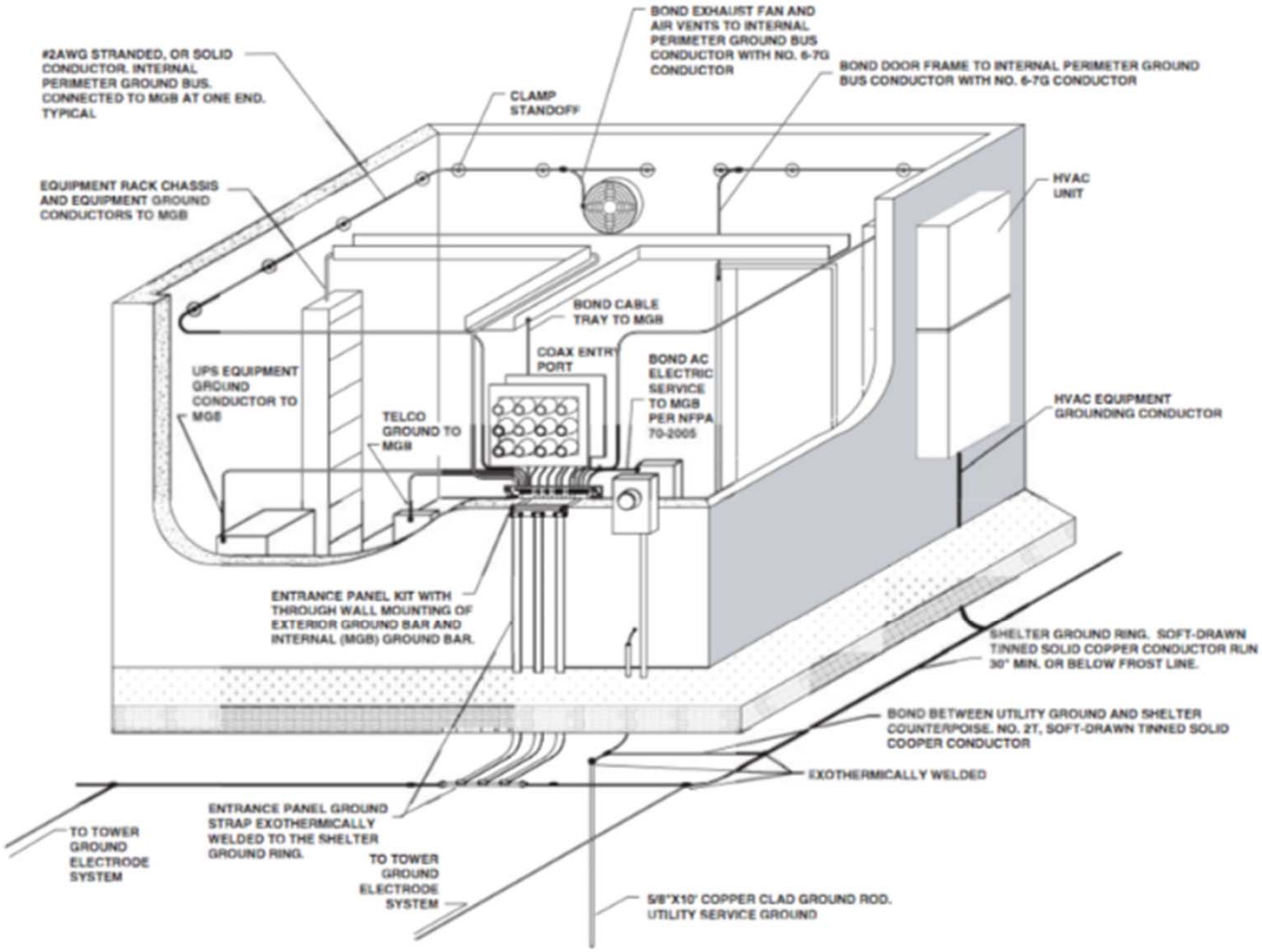


Proper Grounding inside Hut



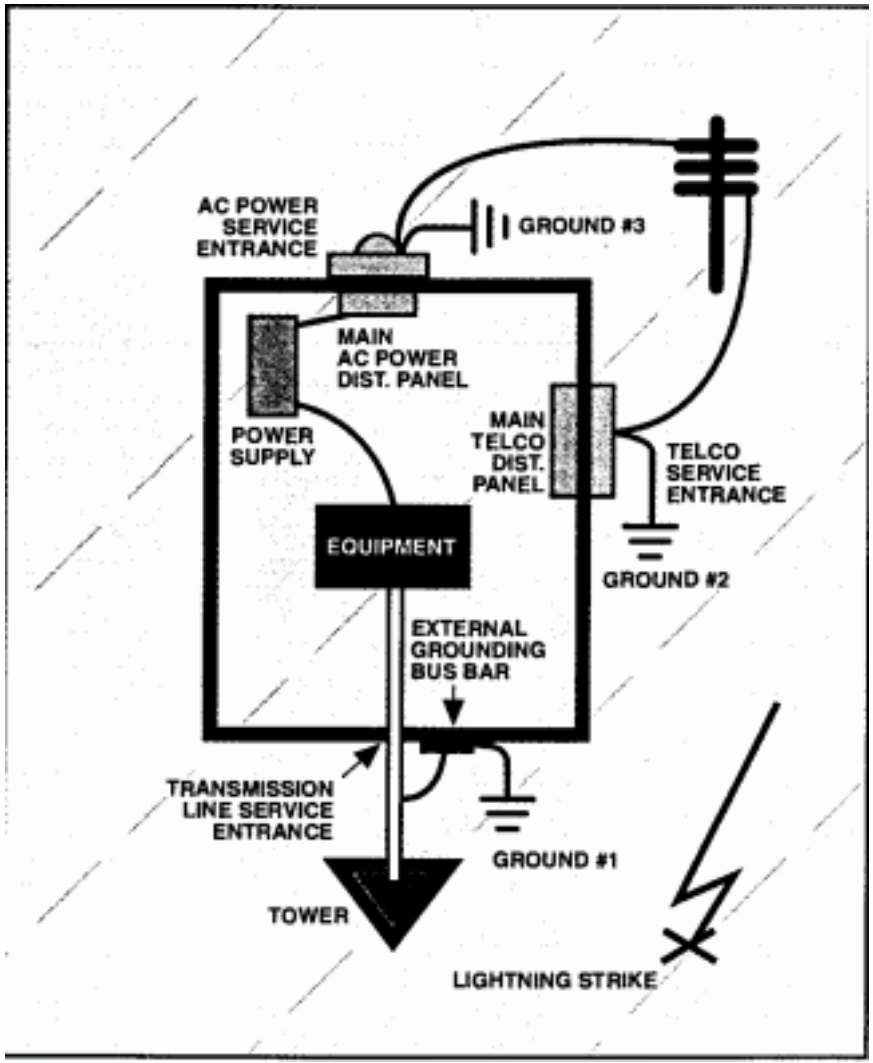
* NOTE: No exterior ground system conductors shown. Electrical service grounding electrode conductor must be bonded to external site ground system.

Showing the grounding outside the Hut



Multipoint Grounding

- The problem:
  - The power supply takes the abuse.
  - It has internal capacitance.
- The fix:
  - Consider using a floating plant
  - Then shorting it out from primary to secondary, right at the power supply



In Summary:
Control where the energy goes

- Pick level of protection desired.
- Place lightning rods appropriately
- Control the impedances properly.
- Reduce the soil ***inductance*** at the place you want the energy to go (green ground plane).

In Summary:
Reduce the voltage seen by the electronics

- Route conductors horizontally between the tower and the hut as close to the soil as possible/practical.
- This will reduce inductance from grounding kits at the tower to the soil and eliminate induced currents, and thus the voltage generated in the surge arrestors at the entry points.
- Reduce inductance at entry panels with copper straps and lower the entry panel as close to soil level as you can.
- Use a single-point (star) ground for the hut and reference it back to your green ground plane. If you must use a multiple point ground, consider shorting out the primary to secondary of the power system, at the power system.

Papers to reference

- Lightning Protection & Grounding Solutions for Communication Sites, 1st Edition, Ken R. Rand
- Erico Lightning Protection Handbook, designing to the IEC 62305 series of lightning protection standards, Pentair
- CenturyLink, Technical Publication, Central Office and Remote Electronic Equipment Environments
- CenturyLink, Technical Publication, Grounding - Central Office and Remote Electronic Equipment Environments
- Motorola Standards and Guidelines for Communication Sites
- International Telecommunication Union, ITU Handbook on Telecommunication Outside Plants in Areas Frequently Exposed to Natural Disasters
- Progress Energy, Network Design Unit, Communications Site Grounding & Bonding Specification

Disclaimer

- Each project is different in nature and location.
- This presentation is meant to be educational only.
- If you follow the advice within and your site blows up, it's on you.
- Feel free to contact us with questions.

Solara Technical Sales

- We define, design and furnish high-availability power solutions for shipment anywhere in the Western Hemisphere.
- Founded September 2001
- Headquarters located in Knoxville, TN
- Systems Integration in Knoxville, TN & Oldsmar, FL
- Owner/President: Kevin Fellhoelter, P.E. (Texas)

Los Angeles Coliseum

Solara Inc.
www.solaratech.com
Kevin Fellhoelter
(214) 906-9853