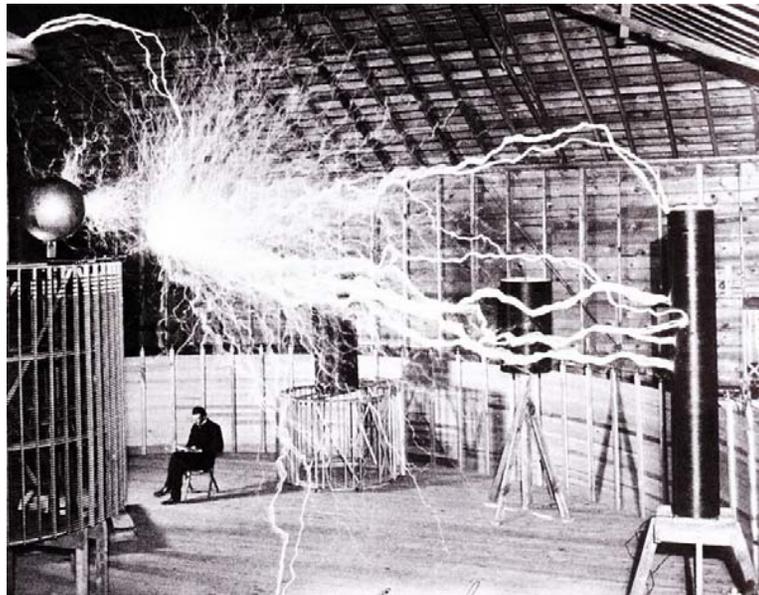


# Practical Lightning Mitigation



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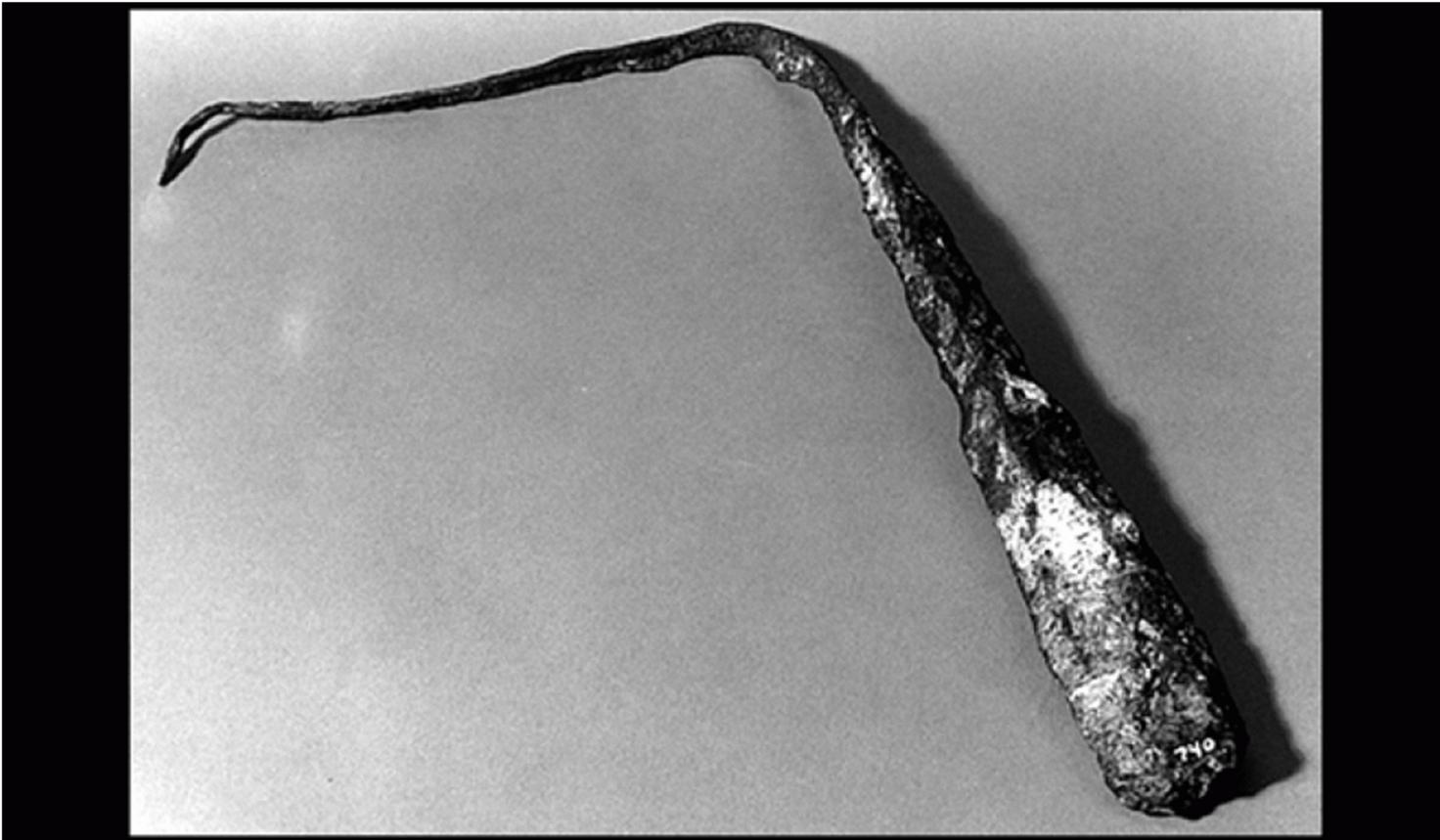
Texas Instruments, Rockwell International, Siemens,  
AT&T Bell Labs, Various smaller technical companies

- 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

- History of lightning protection
- 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 & where low inductance is helpful.

**Know what this is?**



## History of electrical items in buildings & lightning mitigation

- Wires in Buildings
- Rotational Machines
- Linear transformers
- First electronics: Bipolar transistors
- CMOS & FET technologies

## Enter R56

- R56 is a non-proprietary document from Motorola, summarizing various code documents
- Safety of humans first, reliability of equipment, second
- All about grounding things, modified per installation.
- An implicit connection to lightning mitigation design but not a direct one. “Due your best” for each installation.

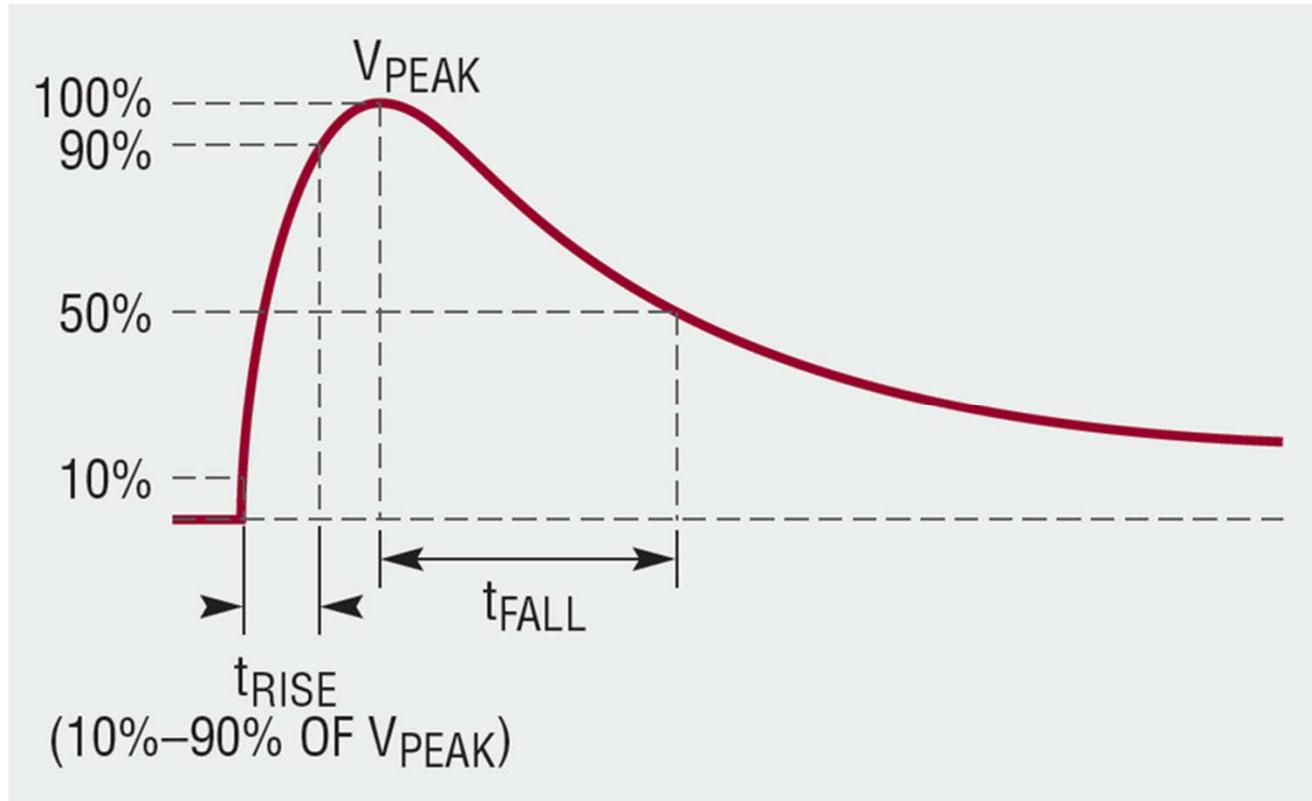
## IEC Terminology

| Term                     | Definition  |
|--------------------------|---|
| <b>Lightning stroke</b>  | Single electrical discharge in a lightning flash to earth. The lightning <b>flash</b> may have multiple strokes |
| <b>Lightning flash</b>   | Electrical discharge of atmospheric origin between cloud and earth consisting of one or more strokes            |
| <b>Multiple stroke</b>   | A lightning flash where more than one stroke (electrical discharge) occurs                                      |
| <b>Point of stroke</b>   | Point where lightning flash strikes earth/object  |
| <b>Lightning current</b> | 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

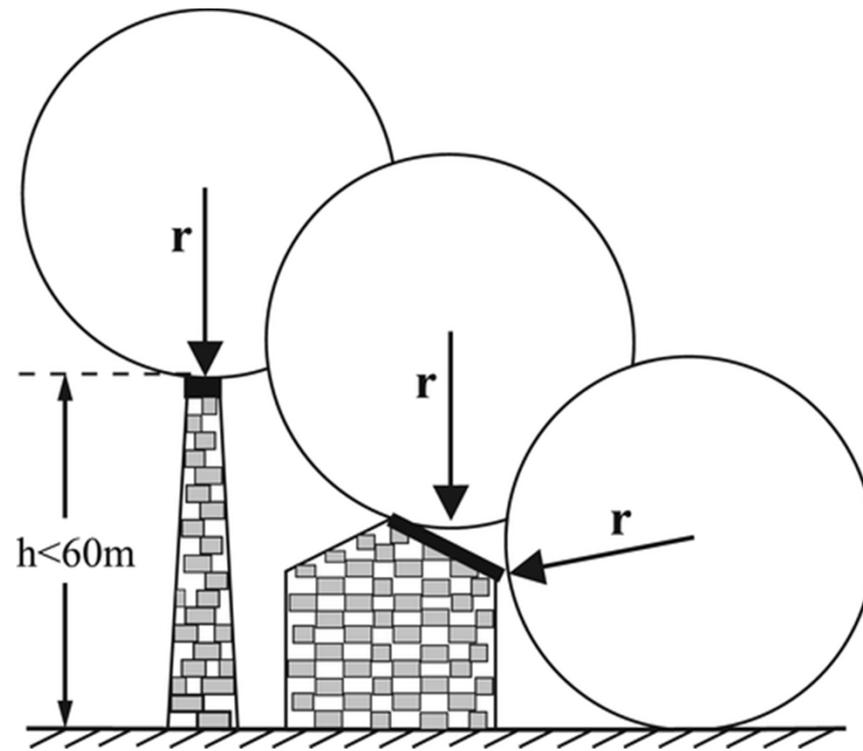
- In the IEC 62305 series, four lightning protection levels are introduced.
- LPL I offers the highest protection level (greatest level of protection), with LPL IV offering the lowest level of protection.

|  | LPL I | LPL II | LPL III | LPL IV |
|--|-------|--------|---------|--------|
| Maximum peak current (kA 10/350 $\mu$ s) | 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

# Rolling Sphere



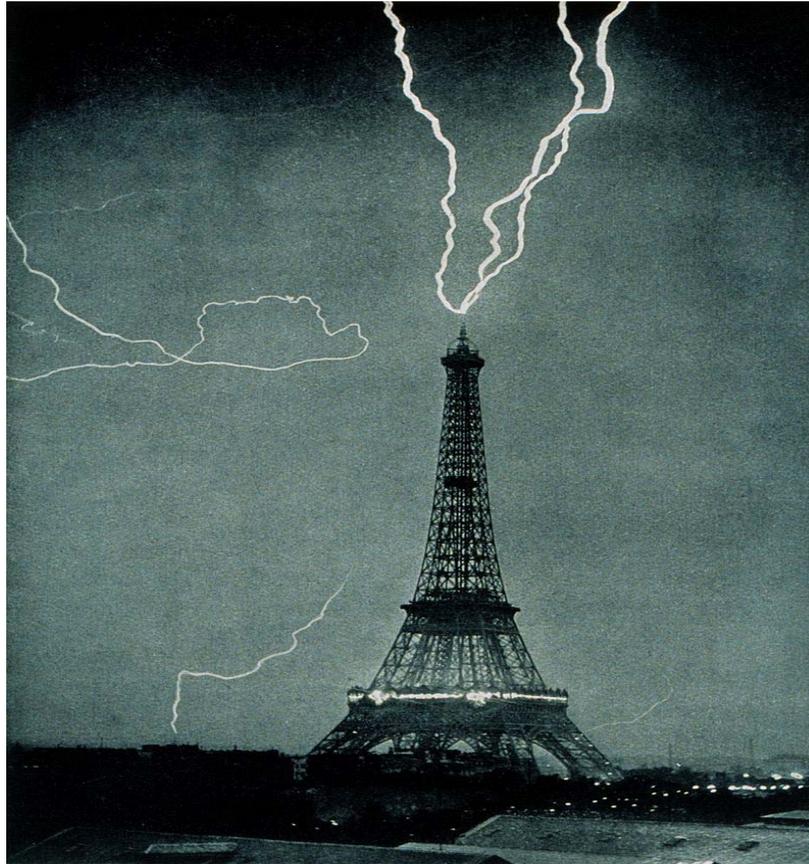
## Lightning Protection Zones

|   | 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     |

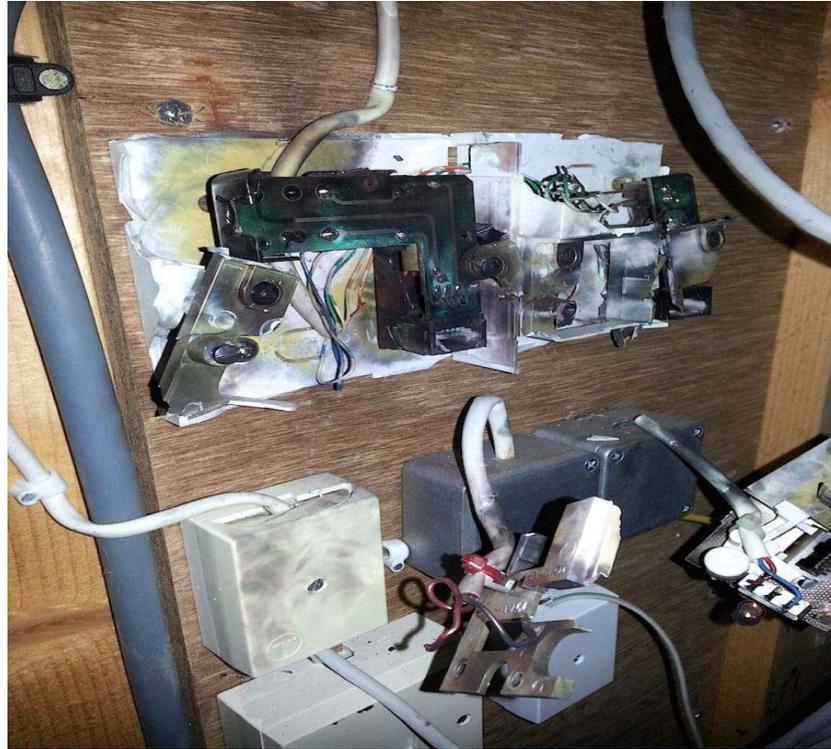
## The Problem: Lightning

- 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**



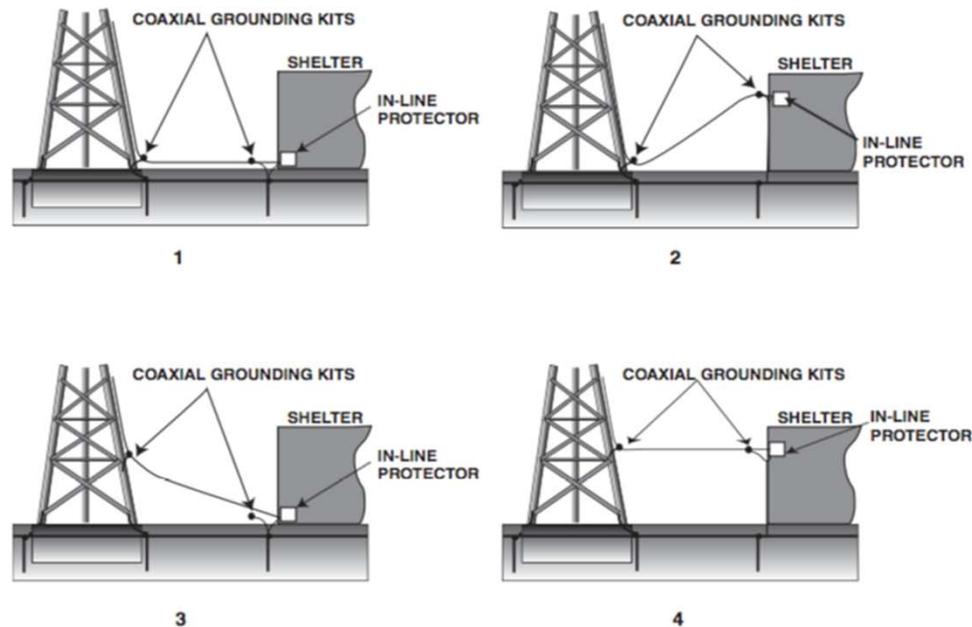
# Damage



## 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 lightning 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)

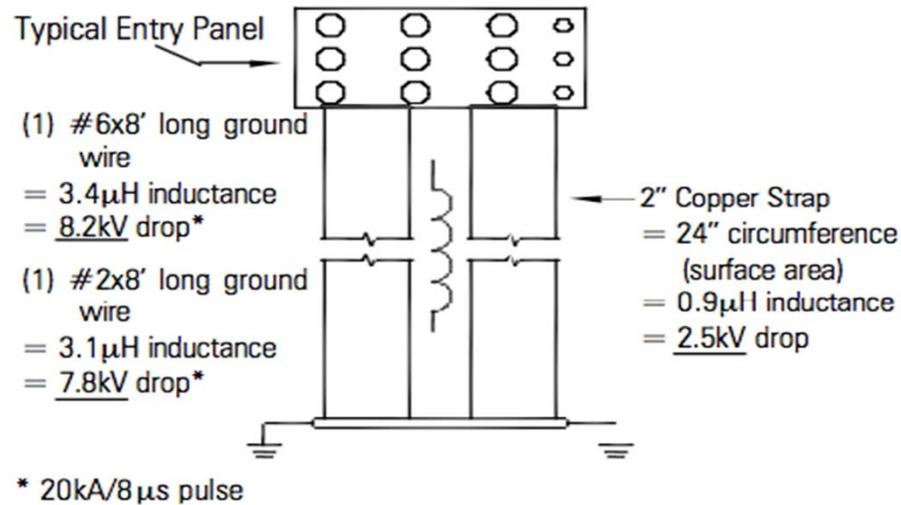
## Two very different Entry Panels



\$

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## 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)

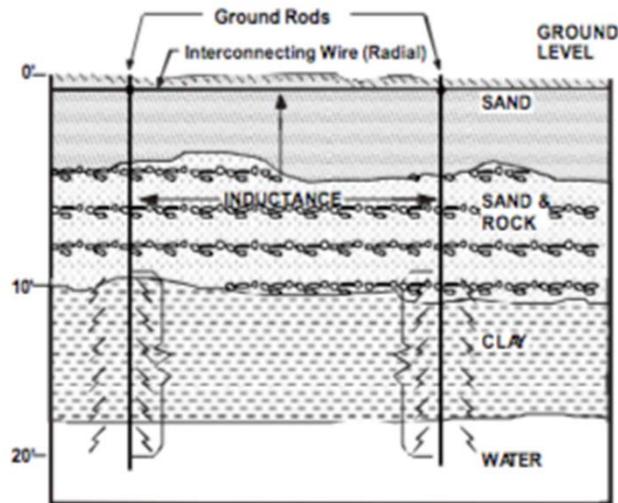


6,000V for 6 feet

$1800\text{V}/6 \text{ conductors} = 300\text{V for } 6' \text{ or } 1/20^{\text{th}} .$

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

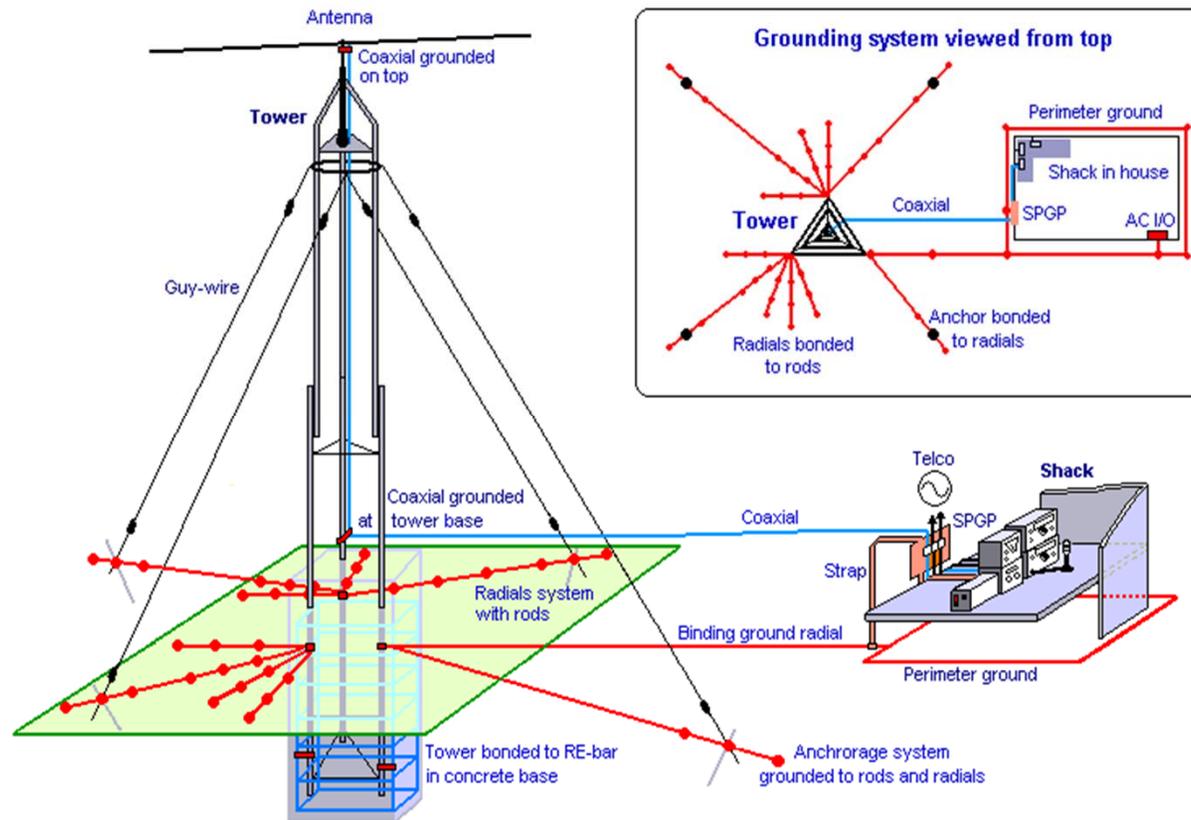
**But Soil is not a perfect ground. Untreated soil is a very poor conductor with high inductance.**



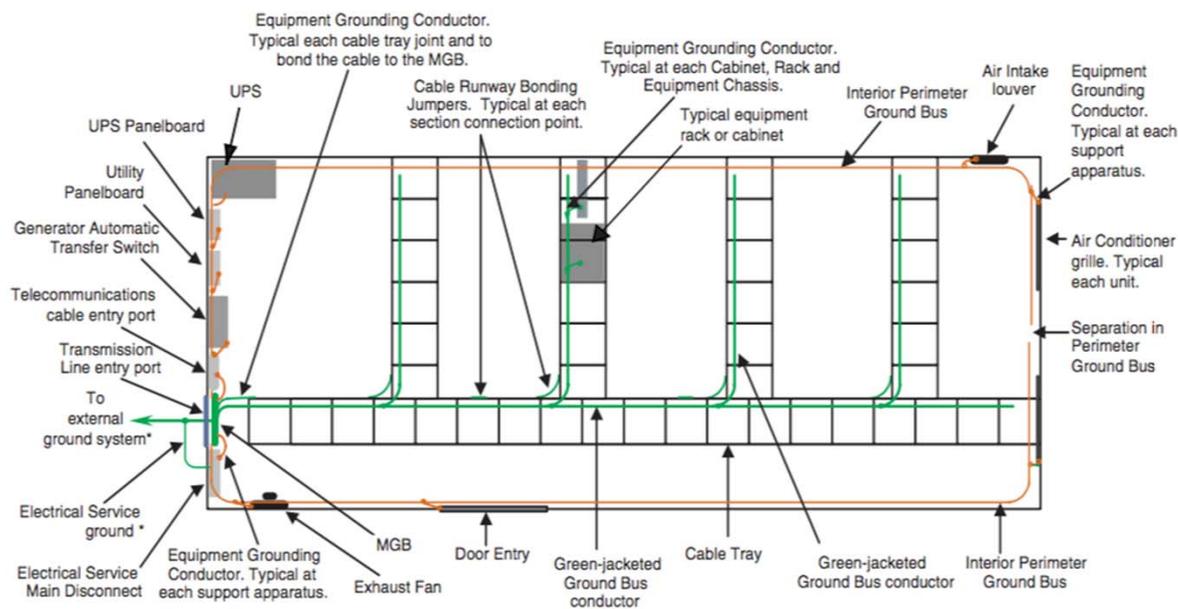
**Now this is a low inductance ground!**



# The Complete Site

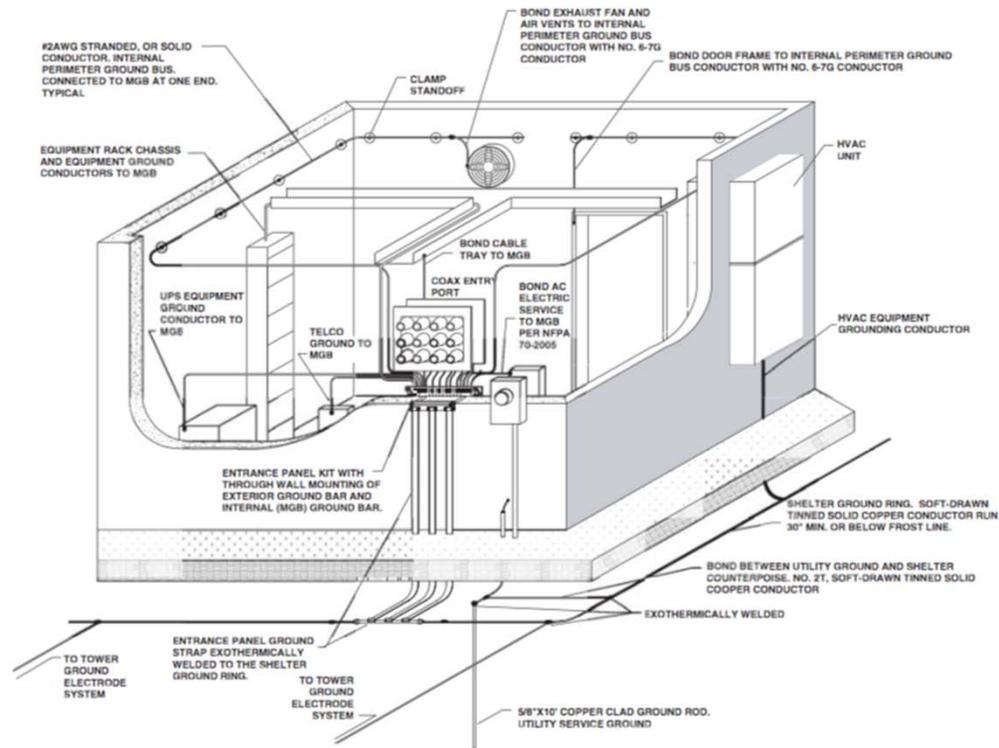


# Proper Grounding inside Hut



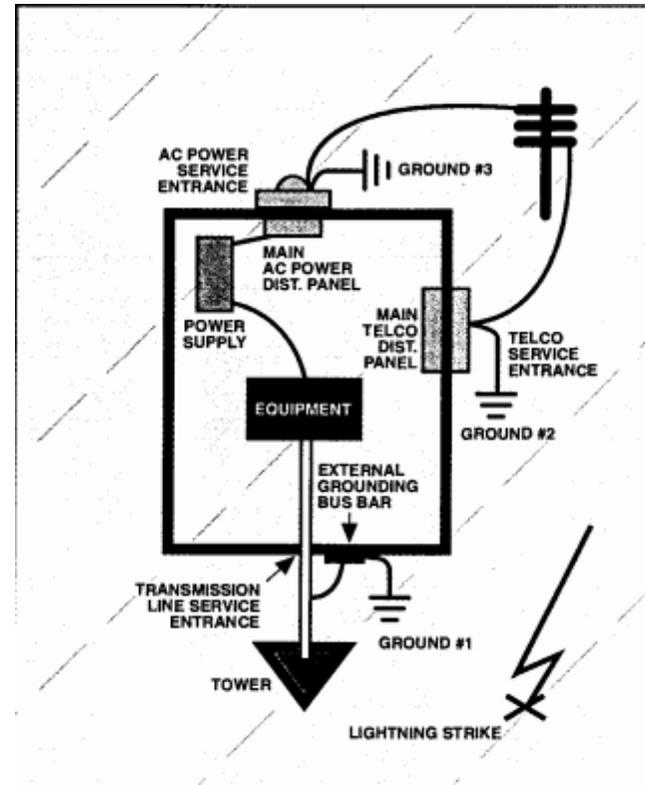
\* NOTE: No exterior ground system conductors shown. Electrical service grounding electrode conductor must be bonded to external site ground system.

# 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, 1<sup>st</sup> 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.

# Los Angeles Coliseum

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