Grounding & Bonding

NEC §100 Purpose of Grounding

- Grounding is one of the means of safeguarding employees, and the public from injury;
- Grounding also allows protective devices to operate during a fault condition;
- The basic theory behind grounding is to keep the voltage of grounded parts as close as possible to the potential of earth, so that a voltage difference does not exist between a person and a grounded metal object.

Grounding & Bonding

- An Electrical Ground is for safety and surge/lightning protection and is **not an RF ground**;
- Electrical Grounding & Bonding is defined in NEC §100 and specified by NEC §250;
- "Grounding" is the connection of a conductor to EARTH through the grounding electrode;
- "Bonding" is connecting two or more "grounding" conductors together

Grounding & Bonding

- **§250 (A) Grounded Systems**
  - **(1) Electrical System Grounding.** Electrical system that are grounded shall be connected to earth in a manner that will limit the voltage imposed by lightning, line surges, or unintentional contact with higher-voltage lines and that will stabilize the voltage to earth during normal operation.

Grounding & Bonding

- **§250 (A) Grounded Systems**
  - **(2) Grounding of Electrical Equipment.** Normally non-current carrying conductive materials enclosing electrical conductors or equipment, or forming part of such equipment, shall be connected to earth so as to limit the voltage to ground on these materials

Grounding & Bonding

- **§250 (A) Grounded Systems**
  - **(3) Bonding of Electrical Equipment.** Normally non-current carrying conductive materials enclosing electrical conductors or equipment, shall be connected together and to the electrical supply source in a manner that established an effective ground-fault current path.

Grounding & Bonding

Informational Note to §250 (A) (1).

An important consideration for limiting the imposed voltage is the routing of bonding and grounding electrode conductors so they **are not any longer than necessary** to complete the connection without disturbing the permanent parts of the installation and so that **unnecessary bends and loops are avoided.**

Grounding & Bonding

NEW REQUIREMENT – NEC 2020

Section 230.67(a) – DWELLINGS

All services supplying dwelling units shall be provided with a surge protection device (SPD)

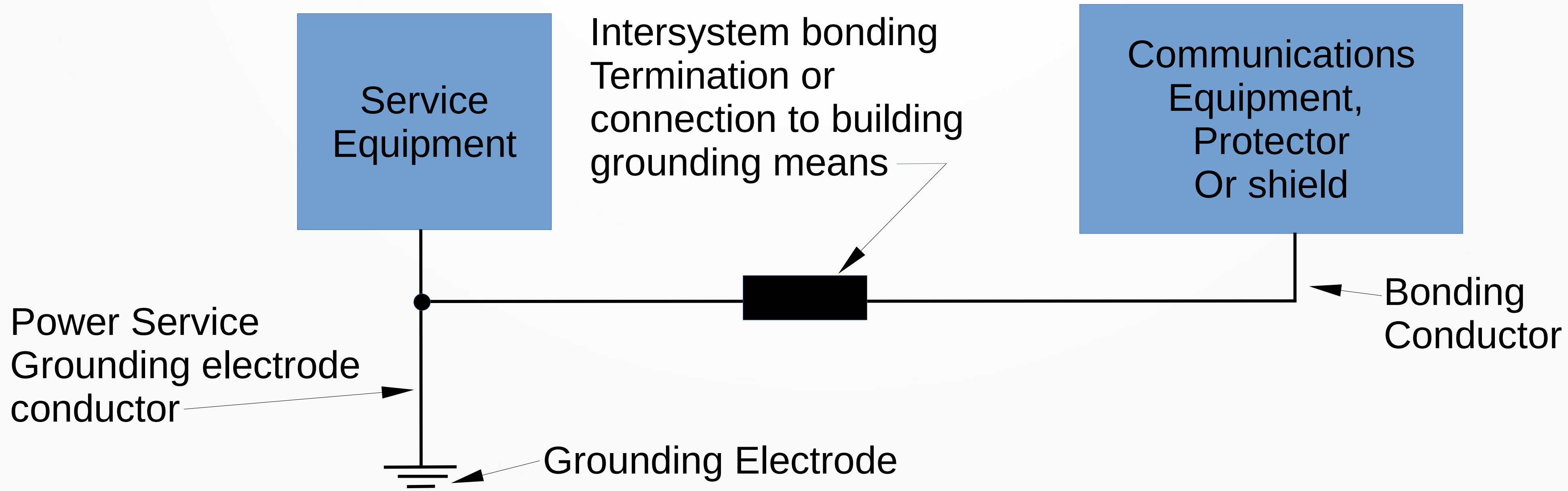
Sensitive electronics and systems found in modern appliances, safety devices (IE: GFCI outlets), smoke alarms, and other equipment in homes, apartments, and other dwellings warrant protection by surge protection devices. If compromised by surges, these systems may be damaged or fail to operate, posing economic and safety concerns.

A Type 1 or Type 2 SPD must be installed at or near the service entrance panel.

Grounding & Bonding

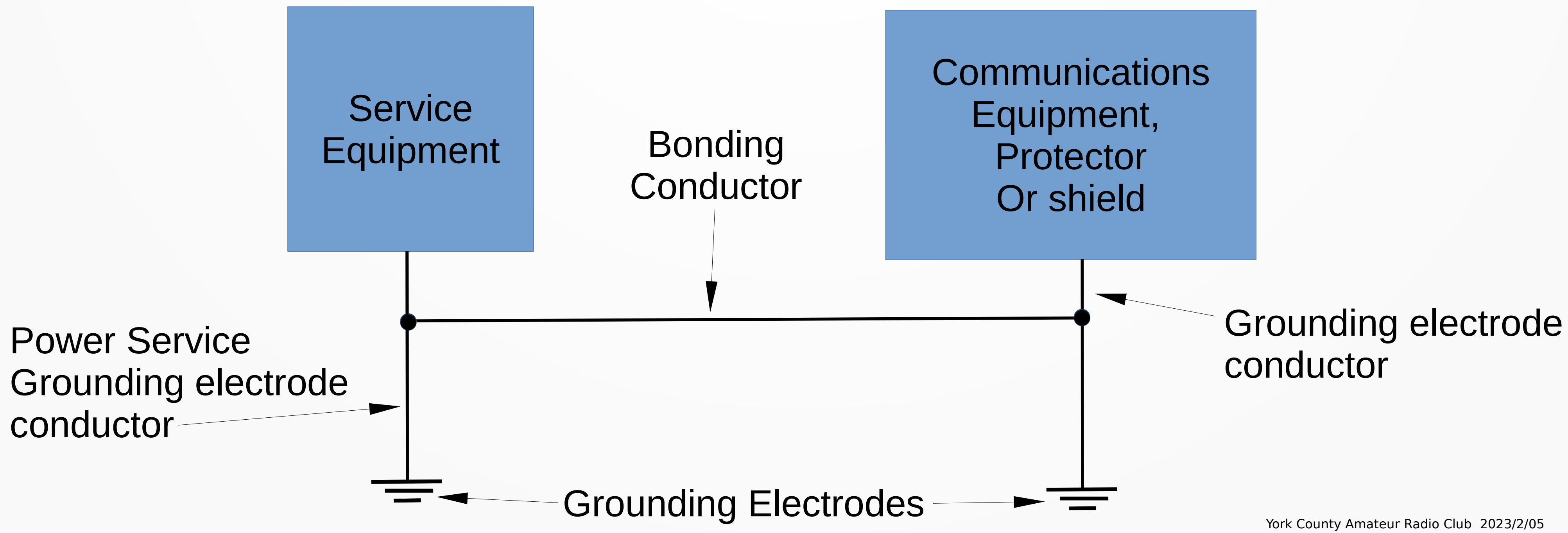
NEC Informational Note 800(a)

Chapter 8 of the NEC requires all communication systems entering a building or structure to be grounded to the electrical system ground (single point ground)

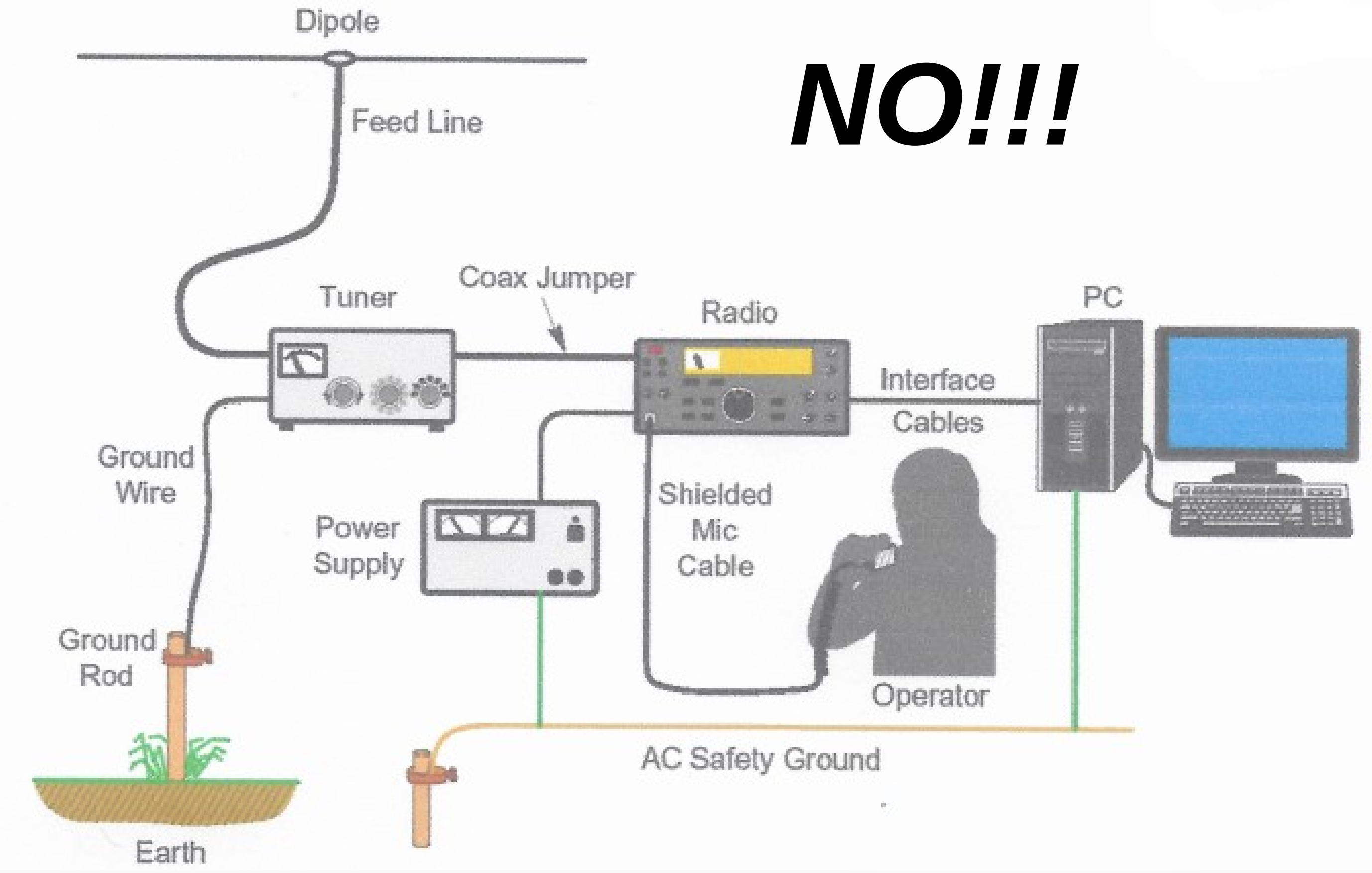


Grounding & Bonding

NEC Informational Note 800(b)



Grounding & Bonding

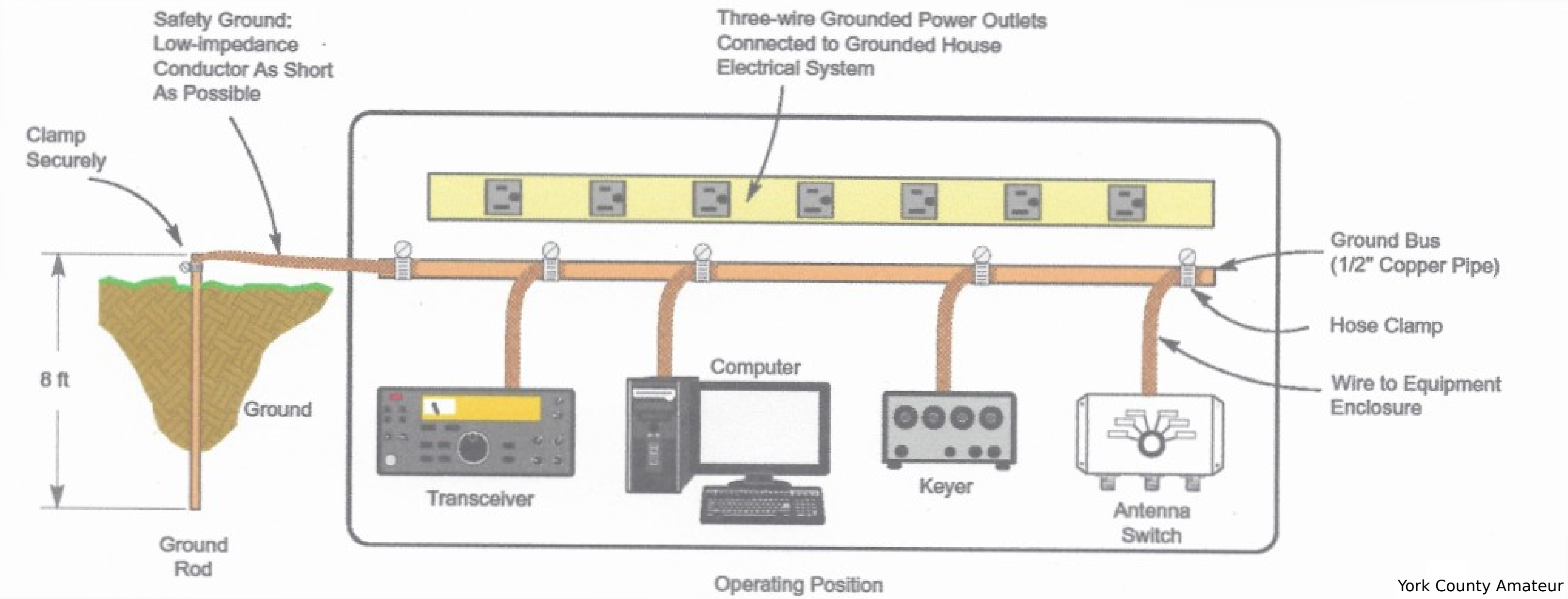


NO!!!

1. No Lightning Protection/ Entrance Panel
2. Ground Rods Not Bonded
3. No bonding to Electrical Entrance ground electrode

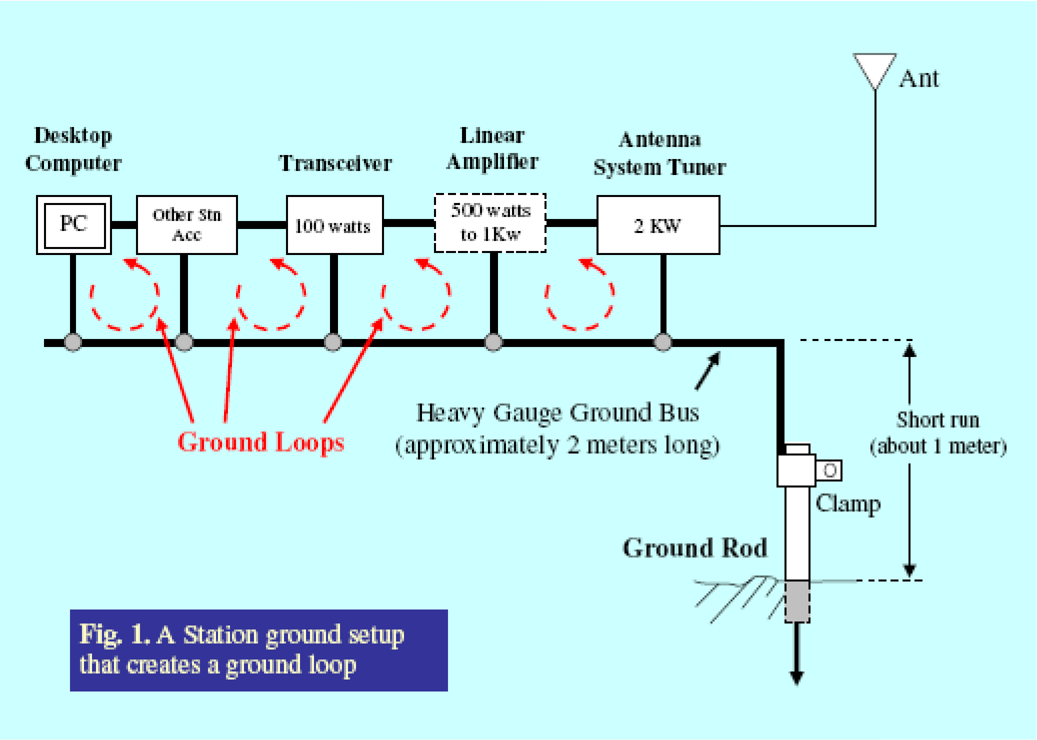
Grounding & Bonding

NO!!!



Grounding & Bonding

WHY PREVIOUS SLIDES ARE INCORRECT



- GROUNDING ELECTRODE NOT BONDED TO SERVICE ENTRANCE
- GROUND BUS TOO LONG
- EQUIPMENT BONDING WIRE DIFFERENT LENGTHS
- GROUND LOOPS CREATE UNEQUAL POTENTIAL BETWEEN EQUIPMENT DURING SURGE CONDITIONS
- GROUND LOOPS MAY CAUSE FAULTY EQUIPMENT OPERATION UNDER NORMAL CONDITIONS

Grounding & Bonding

WHAT IS CORRECT?

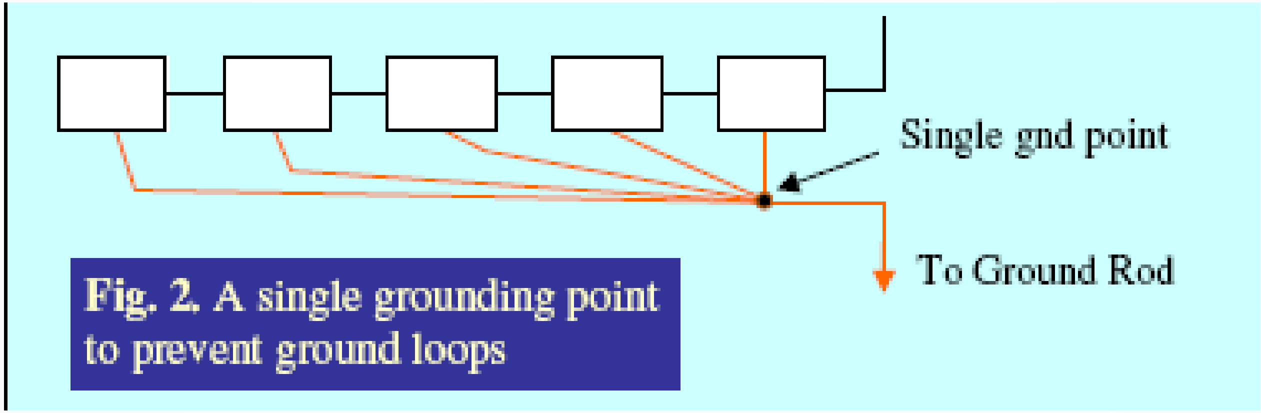


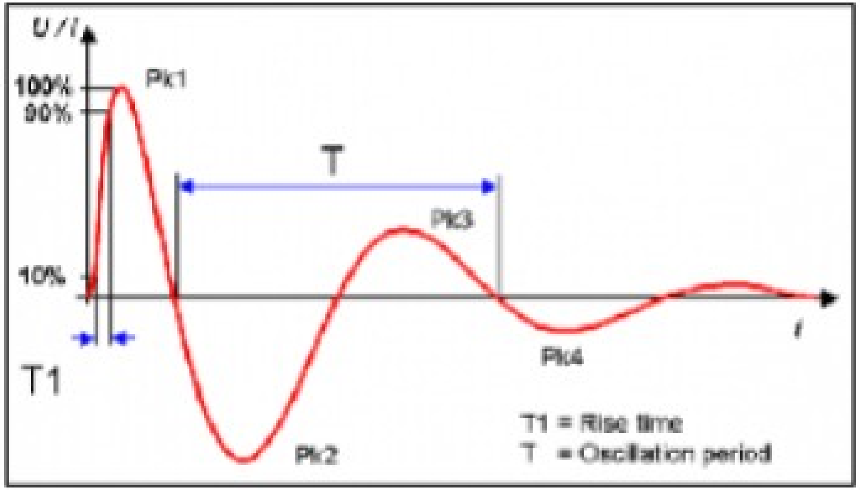
Fig. 2. A single grounding point to prevent ground loops

- BETTER – BUT IS IT GOOD ENOUGH?
- EACH BONDING CONDUCTOR SHOULD BE EQUAL LENGTH

Grounding & Bonding

CONSIDER A POWER LINE SURGE - 100 kHz RING WAVE OF 4kV / 2kA

(IEEE C62.41, TYPICAL POWER-LINE SURGE)



T1 = 1.2µS
T = 200µS

USING OHMS LAW: E = I x R

IF ONE EQUIPMENT BONDING WIRE IS 0.05Ω
2,000 x 0.05 = 100 V

IF SECOND EQUIPMENT BONDING WIRE IS 0.25Ω
2,000 X 0.25 = 500 V

VOLTAGE DIFFERENCE BETWEEN THE TWO IS
500 – 100 = **400 V**

USING TRUE IMPEDANCE *j*X VOLTAGE WILL BE GREATER

Grounding & Bonding

ANOTHER COMMON MISTAKE

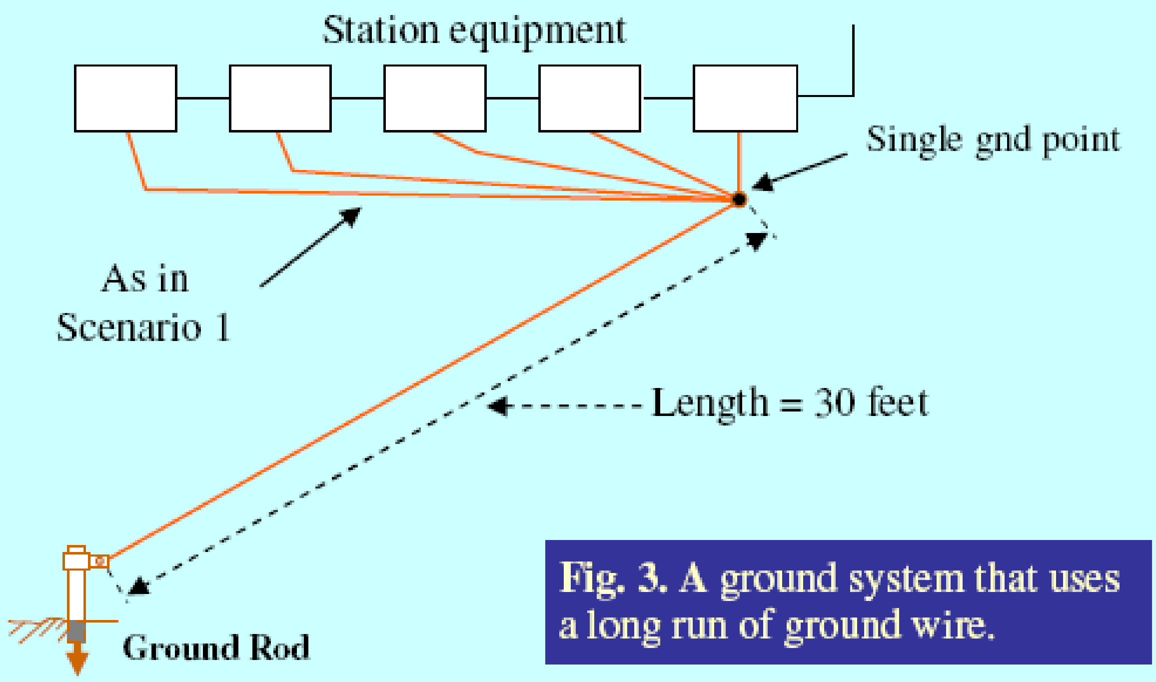


Fig. 3. A ground system that uses a long run of ground wire.

Grounding & Bonding

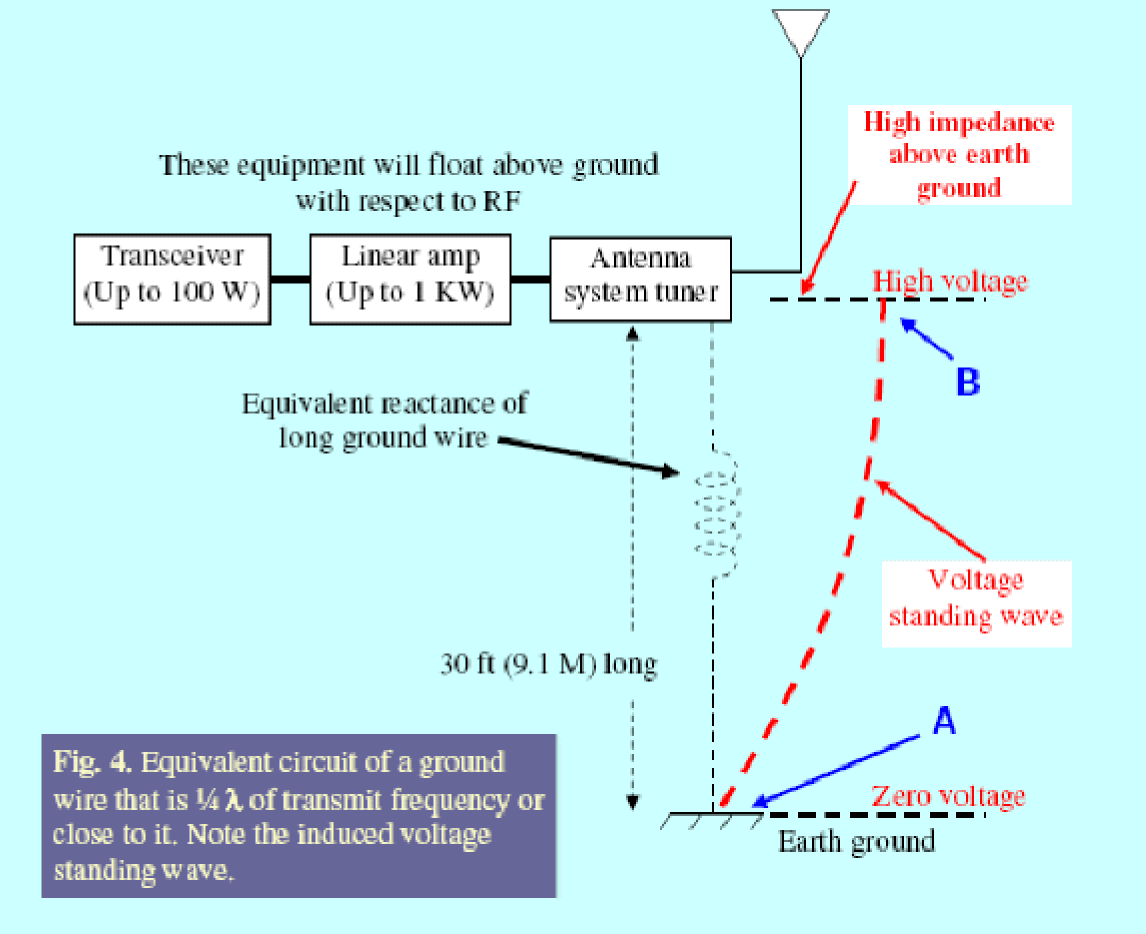
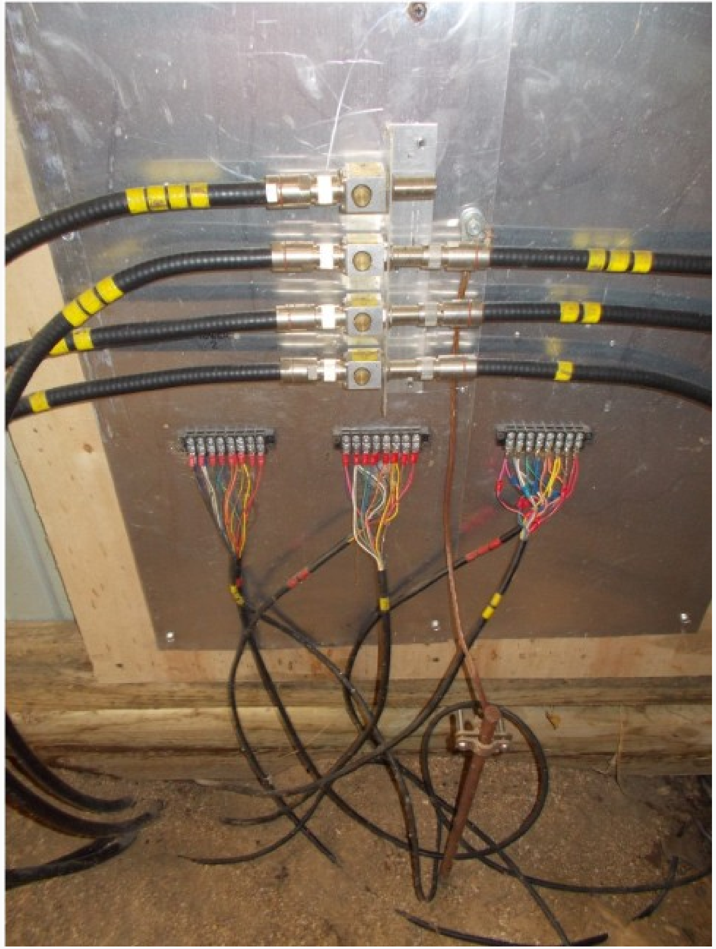


Fig. 4. Equivalent circuit of a ground wire that is ¼ λ of transmit frequency or close to it. Note the induced voltage standing wave.

Grounding & Bonding

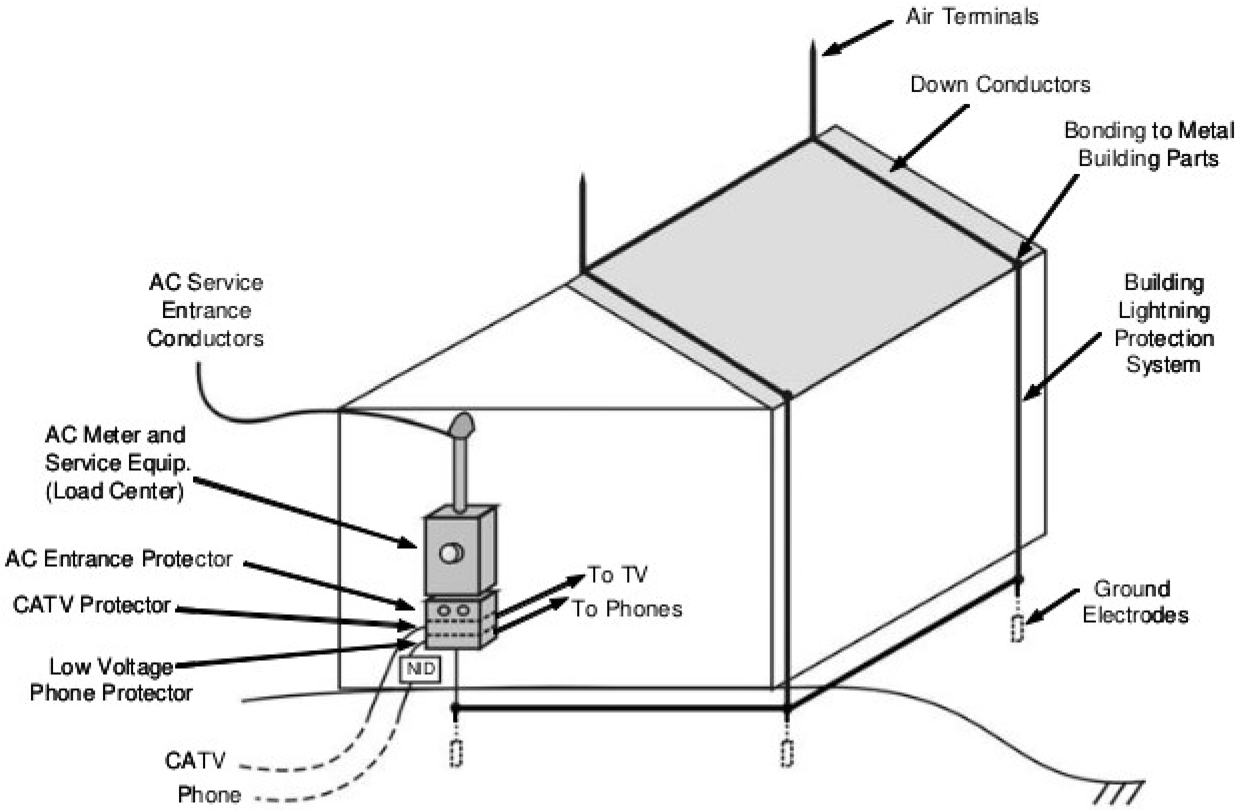


EXAMPLE OF “SINGLE-POINT PANEL” IN PRESENTATION GIVEN AT 2016 DAYTON HAMFEST

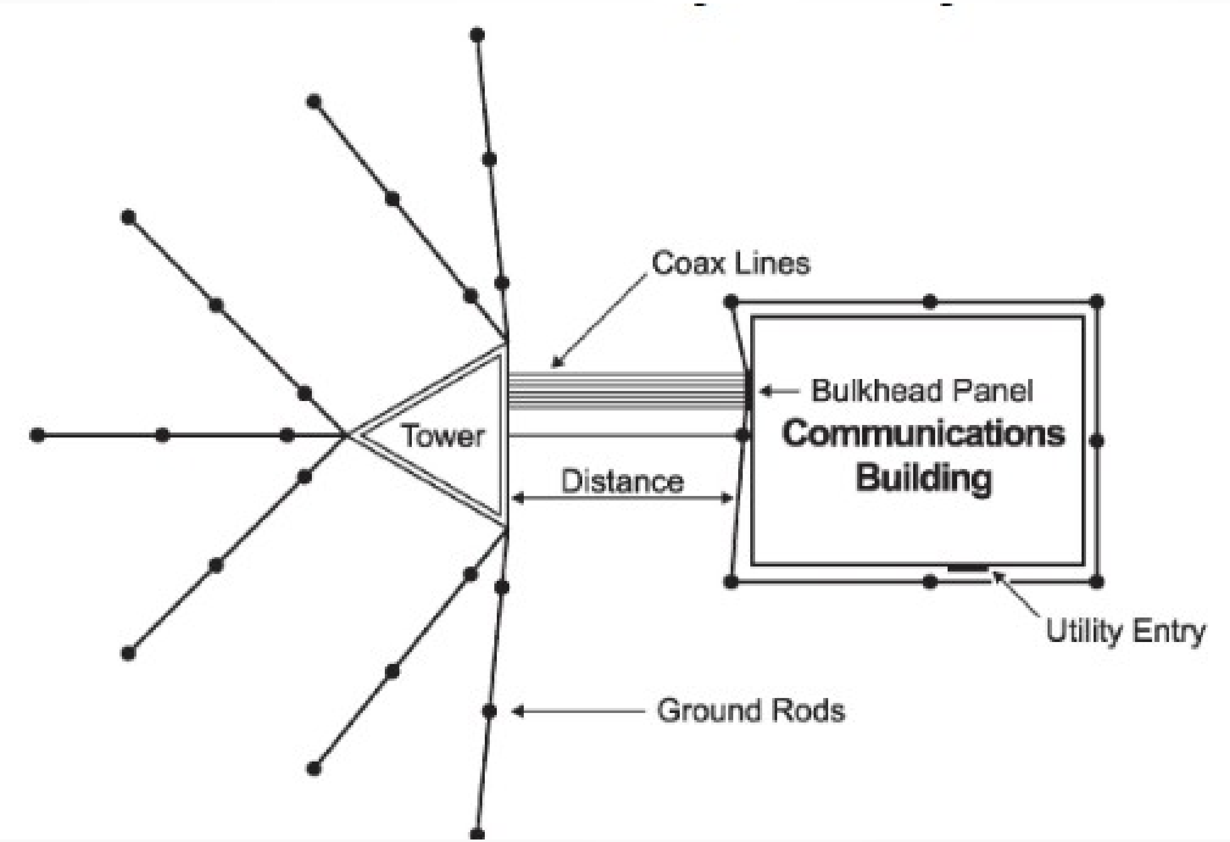
WHAT’S WRONG?

- ***NO* BONDING** OF GROUND ELECTRODE TO ELECTRICAL SERVICE ELECTRODE
- ***NO* SURGE PROTECTION** ON CONTROL WIRES
- ***DISSIMILAR METALS***

Grounding & Bonding



Grounding & Bonding



Grounding & Bonding

GROUNDING ELECTRODE

NEC §250.52 GROUNDING ELECTRODES

NEC §250.52 (A) (5) "… SHALL NOT BE LESS THAN 2.44 METERS (8FT) IN LENGTH…"

NEC §250.52 (A) (5) (b) "ROD TYPE GROUNDING ELECTRODES …. SHALL BE 15.87mm (5/8") IN DIAMETER, UNLESS LISTED.

Grounding & Bonding

GROUNDING ELECTRODE

NEC §250.53 (A) (2) “SUPPLEMENTAL ELECTRODE REQUIRED. A SINGLE ROD, PIPE, OR PLATE ELECTRODE SHALL BE SUPPLEMENTED BY AN ADDITIONAL ELECTRODE.

EXCEPTION: If a single rod, pipe, or plate grounding electrode has a resistance to earth of ***25 Ω*** *or less, the supplemental electrode shall not be required.*

Grounding & Bonding

Earth Resistivity

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
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

Grounding & Bonding

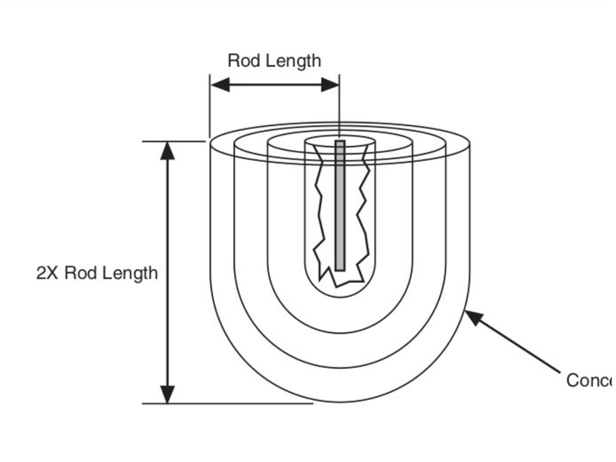
Earth Resistivity Factors

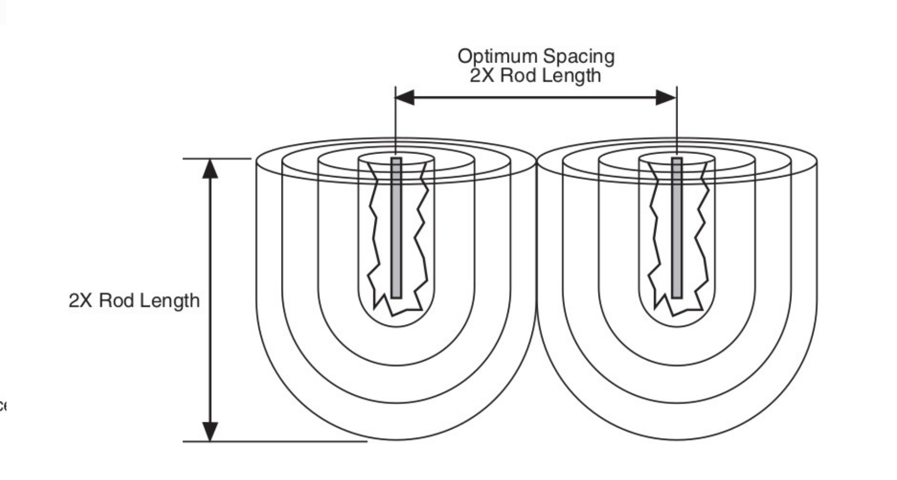
- Earth resistivity is determined by:
  - Contact resistances of the grounding conductor to the electrode
  - Type of grounding electrode
  - Number of grounding electrodes
  - Soil resistivity (salt, mineral, and moisture content)

Grounding & Bonding

Why Measure Earth Resistivity?

- Earth resistivity is used to estimate:
  - Ground impedance of a grounding system
  - Earth potential gradients to estimate step & touch voltages



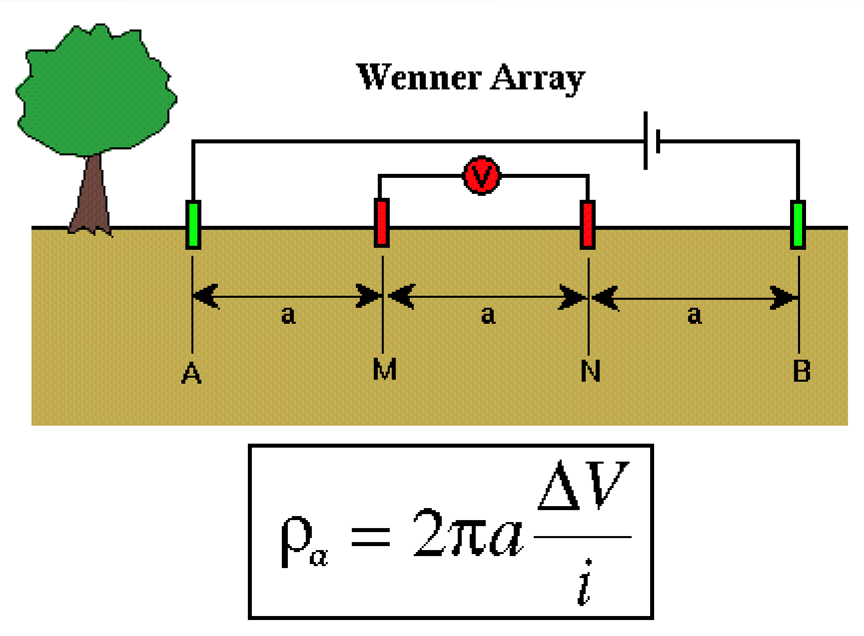


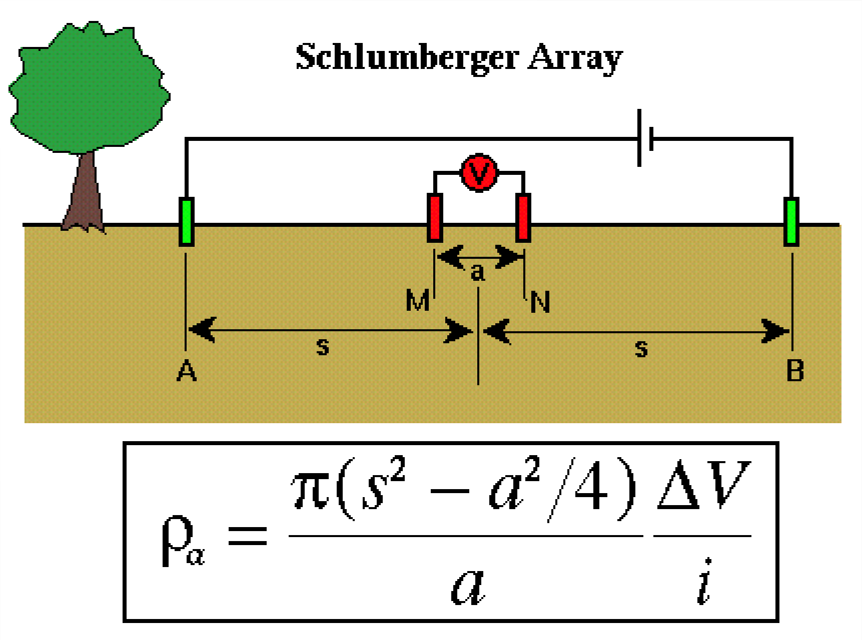
Grounding & Bonding

Measuring Earth Resistivity

- Several commercial test instruments available
- ***CANNOT USE AN OHMMETER***
- Measurements:
  - Three-pole, Fall of Potential Method
    - Not Recommended – requires disconnecting grounding conductor
  - Four-pole Wenner Array
    - Simplest method
  - Four-pole Schlumberger Array
    - Most effective method

Grounding & Bonding



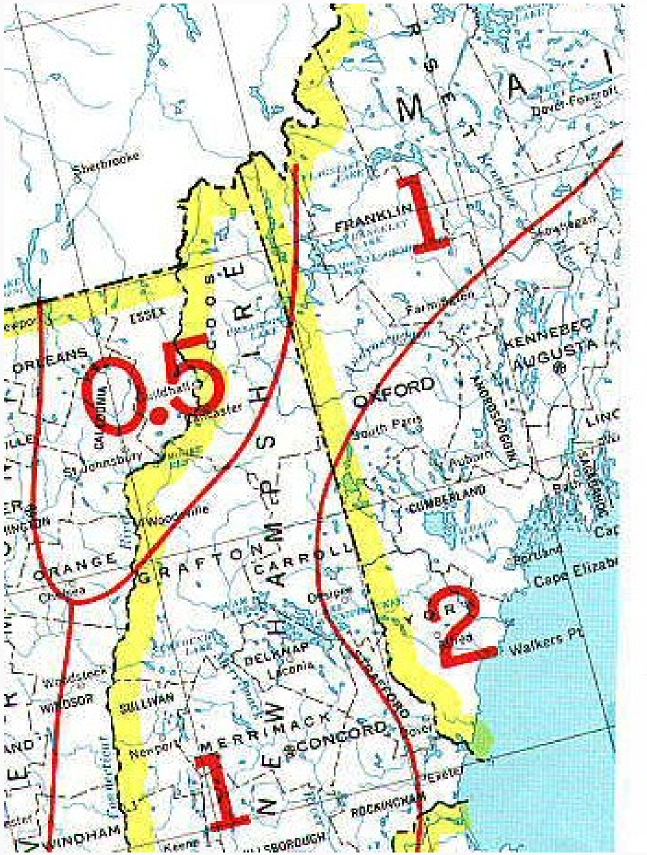


Grounding & Bonding

- https://www.nfpa.org/NEC/About-the-NEC/Grounding-and-bonding
- National Weather Service, Engineering Handbook No. 3 – Facilities, Chapter 11a – Lightning Protection https://w1yca.org/tech.html under the GROUNDING & BOUNDING category
- National Electric Safety Code: §100, §200, &250, & §800

Grounding & Bonding

Earth Conductivity



Measured in millisiemens per meter (mS/m)

Siemens is an SI unit of electrical conductance

$S = 1\ \Omega^{-1}$ $(1 / \Omega)$