Applying the NEC® to Amateur Radio

By Tim Kuhlman, PE

KD7RUS

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Purpose of this Course

- Detail Review of the National Electrical Code® as it Applies to Amateur Radio
  - Overview of the NEC® Structure
  - Define Article 810 for Amateur Radio.

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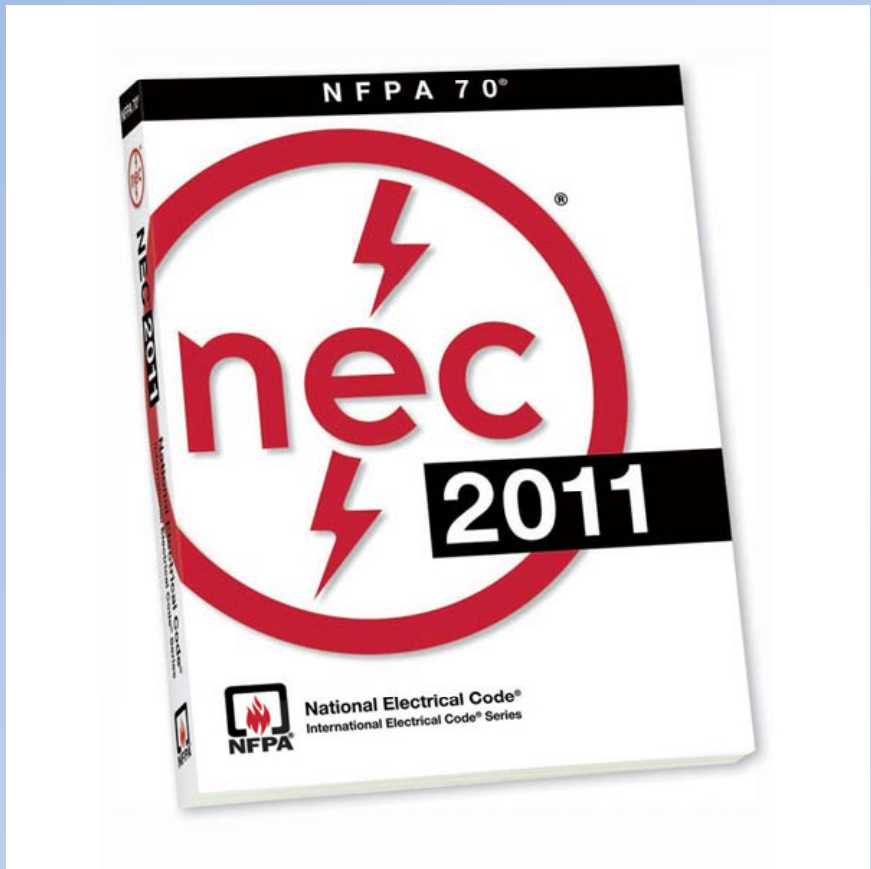
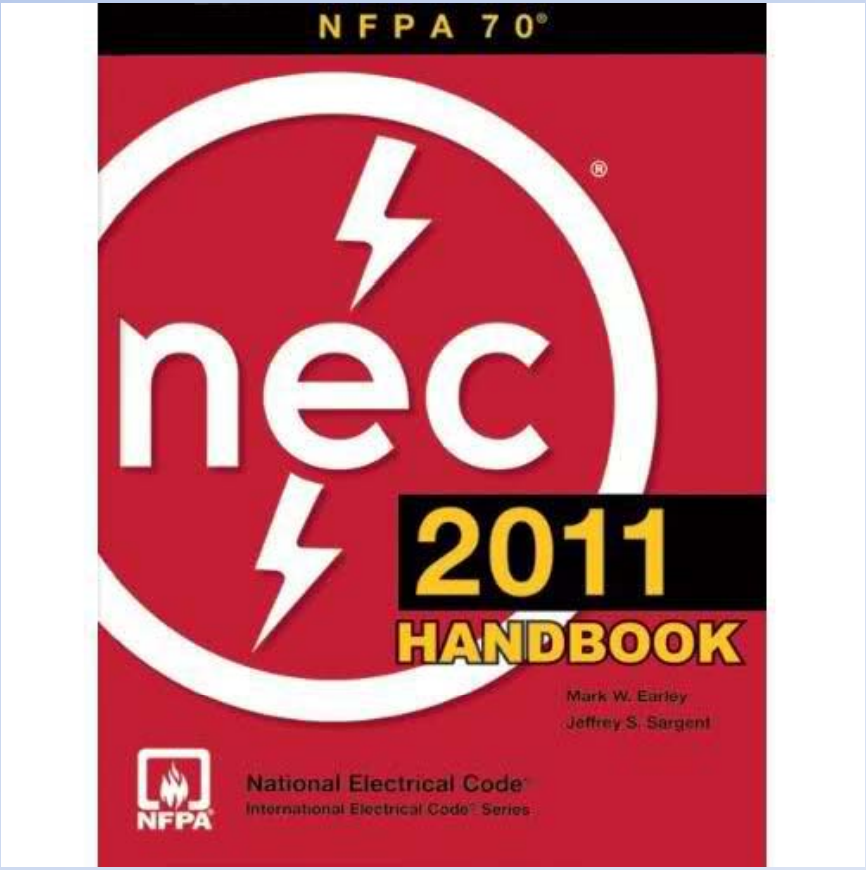
References





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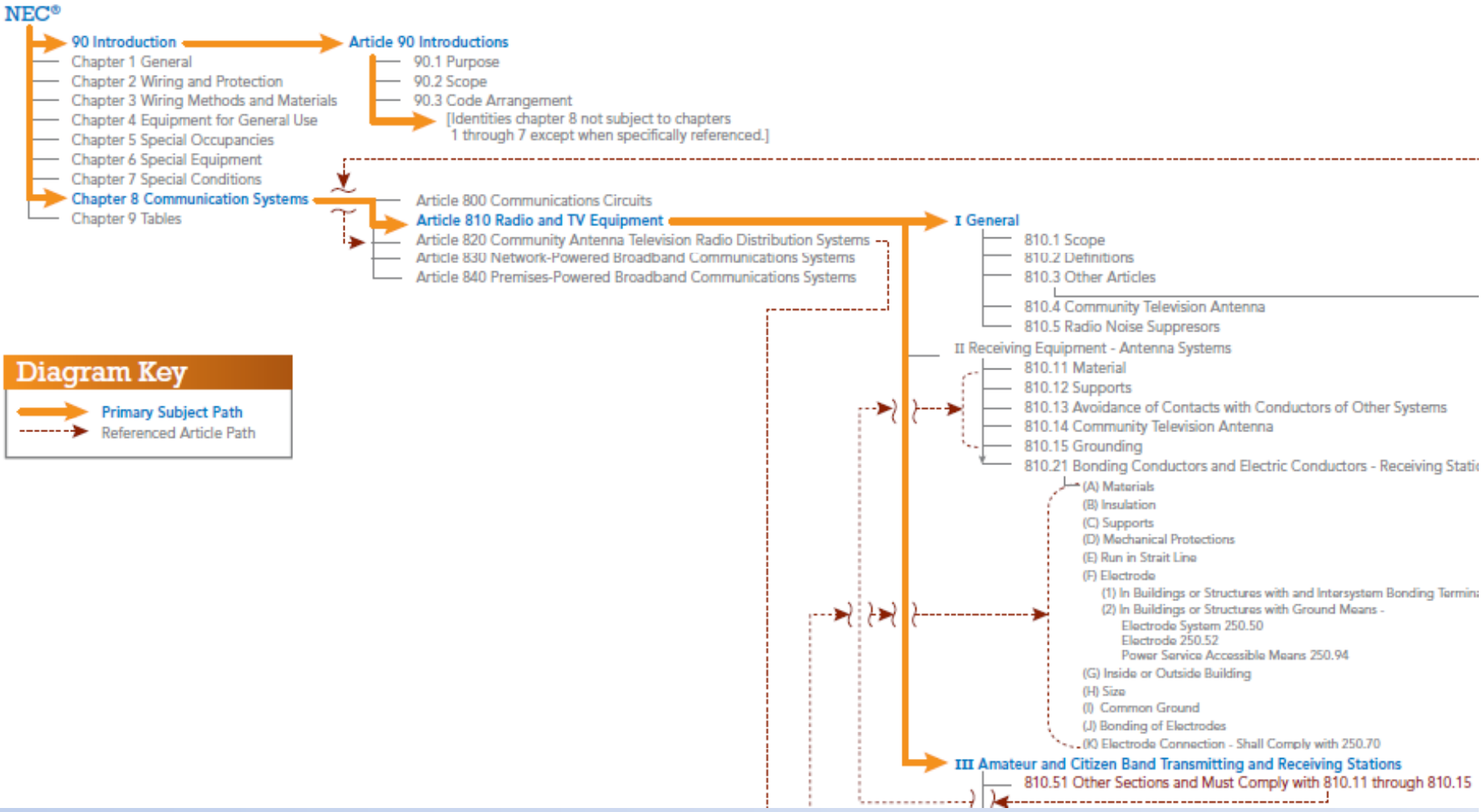
References

The National Electric Code® - Article 810, Part III Code Relation Diagram



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Where to Start?

- Start at the Beginning
- The National Electrical Code® – NEC® is a not written for the layman or meant to be easily understood by those not in the trade.

Purpose of the Code

- 90.1 Purpose

(A) Practical Safeguarding. The purpose of this *Code* is the practical safeguarding of persons and property from hazards arising from the use of electricity.

(B) Adequacy. This *Code* contains provisions that are considered necessary for safety. Compliance therewith and proper maintenance results in an installation that is essentially free from hazard but not necessarily efficient, convenient, or adequate for good service or future expansion of electrical use.

- The NEC® is not concerned with a system performance unless it directly affects safety.

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Purpose of the Code

- 90.1 Purpose

> **(C) Intention.** This *Code* is not intended as a design specification or an instruction manual for untrained persons.

- There is an expectation by the authors of the Code that the person applying it have experience and are trained.

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Enforcement

90.4 Enforcement. This *Code* is intended to be suitable for mandatory application by governmental bodies that exercise legal jurisdiction over electrical installations, including signaling and communications systems, and for use by insurance inspectors. The authority having jurisdiction for enforcement of the *Code* has the responsibility for making interpretations of the rules, for deciding on the approval of equipment and materials, and for granting the special permission contemplated in a number of the rules.

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Disclaimer and Enforcement

- Enforceable by the AHJ (Authority Having Jurisdiction). Also known as the Building Inspector.
- Interpreted by the AHJ through it's enforcement.
- The interpretations of what you may have to apply may be different than what we discuss today.

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Scope of the Code

- Article 90 Introduction

(A) Covered. This *Code* covers the installation of electrical conductors, equipment, and raceways; signaling and communications conductors, equipment, and raceways; and optical fiber cables and raceways for the following:

(1) Public and private premises, including buildings, structures, mobile homes, recreational vehicles, and floating buildings

(2) Yards, lots, parking lots, carnivals, and industrial substations

(3) Installations of conductors and equipment that connect to the supply of electricity

(4) Installations used by the electric utility, such as office buildings, warehouses, garages, machine shops, and recreational buildings, that are not an integral part of a generating plant, substation, or control center.

90.3 Code Arrangement

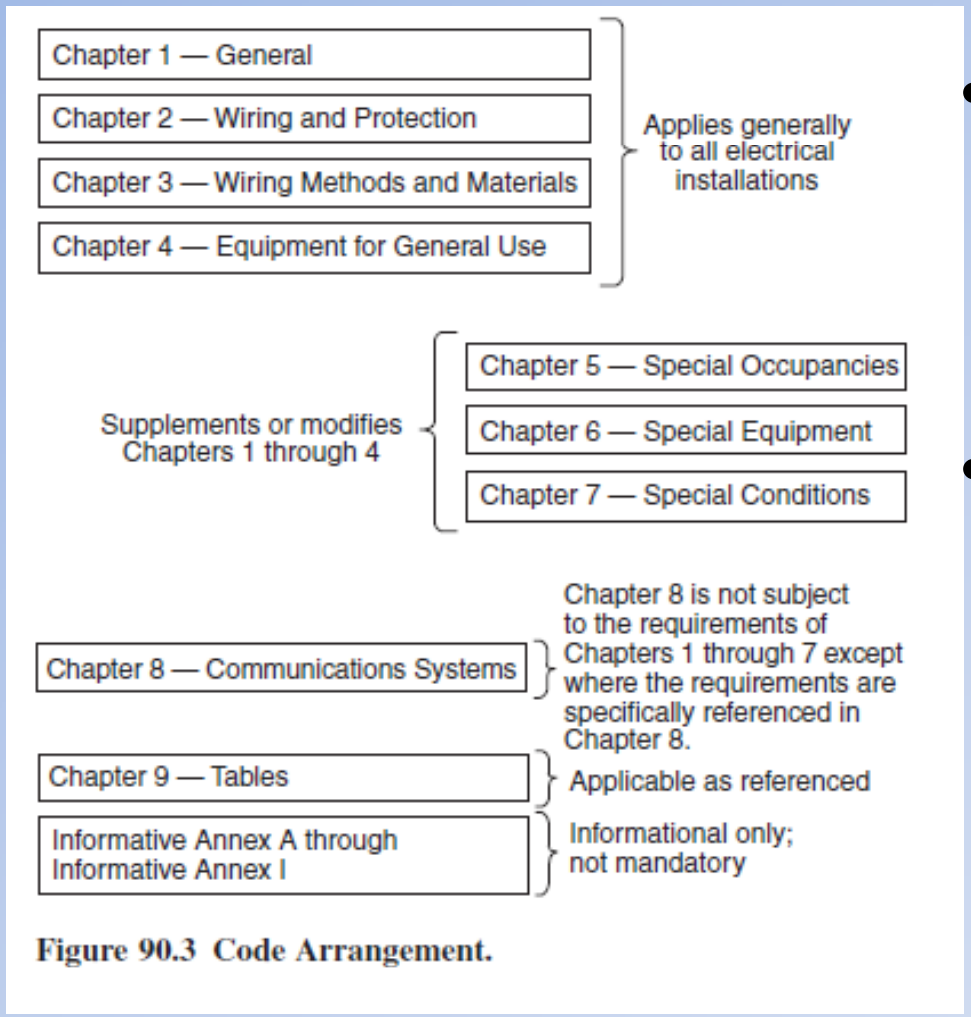

Figure 90.3 Code Arrangement.

- Chapters 1, 2, 3 & 4 generally apply unless amended by Chapters 5, 6 or 7.
- Unless Chapter 8 references another section of the Code, that section does not apply to a Chapter 8 item.

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NEC Table of Contents

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Article 810 Defined

- Article 810 Radio and Television Equipment

I. General

810.1 Scope. This article covers antenna systems for radio and television receiving equipment, amateur and citizen band radio transmitting and receiving equipment, and certain features of transmitter safety. This article covers antennas such as wire-strung type, multi-element, vertical rod, and dish and also covers the wiring and cabling that connects them to equipment. This article does not cover equipment and antennas used for coupling carrier current to power line conductors.

This is typical Code language that is not the easiest to understand.

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Article 810 Defined

- Article 810 Radio and Television Equipment
  - 810.1 Scope.
    - This article covers:
      - antenna systems for radio and television receiving equipment,
      - amateur and citizen band radio transmitting and receiving equipment, and certain features of transmitter safety.
      - antennas such as:
        - » wire-strung
        - » multi element
        - » vertical rod,
        - » and dish and also covers the wiring and cabling that connects them to equipment.

Tip: Re-writing the run on sentence into separate sentences makes it easier to understand.

Article 810 Defined

- Article 810 segmented into 3 parts
  - I. General
  - II. Receiving Equipment – Antenna Systems
  - III. Amateur and Citizen Band Transmitting and Receiving Stations – Antenna Systems
  - IV. Interior Installation - Transmitting Stations
- Part 1 General, Part 3 Amateur…, and other references within these two parts of this Article, apply to your amateur station.
- Part 3 only covers paragraphs 810.51 through 810.58.
- Part 2 Receiving Equipment – Antenna Systems and Part 4 Interior Installations – Transmitting Stations does not apply to an Amateur Station.

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Article 810 General Part 1

- Article 810 Part 1 General (810.1 through 810.5)
  - 810. 1 Scope
  - 810. 2 Definitions – See Article 100
  - 810. 3 Other Articles
    - Wiring from the source of power to and between devices connected to the interior wiring system shall comply with Chapters 1 through 4 other than as modified by Parts I and II of Article 640.
    - Wiring for audio signal processing, amplification, and reproduction equipment shall comply with Article 640.
    - Coaxial cables that connect antennas to equipment shall comply with Article 820 (Community Antenna Television & Radio Distribution Systems).

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Article 810 General Part 1

- Article 810 Part 1 General (810.1 through 810.5)
  - 810.4 Community Television Antenna
  - 810.5 Radio Noise Suppressors
    - Radio interference eliminators, interference capacitors, or noise suppressors connected to power-supply leads shall be of a listed type. They shall not be exposed to physical damage.

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Article 810 Part III Amateur Transmitting and Receiving Stations – Antenna Systems.

- Part 3, Amateur Stations – is a short section of the Code.
- It is paragraphs 810.51 to 810.58 along with other references from within these paragraphs.

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Article 810 Part III Amateur Transmitting and Receiving Stations – Antenna Systems.

III. Amateur and Citizen Band Transmitting and Receiving Stations — Antenna Systems

810.51 Other Sections. In addition to complying with Part III, antenna systems for amateur and citizen band transmitting and receiving stations shall also comply with 810.11 through 810.15.

- 810.51 refers to 5 paragraphs in Part 2 that apply 810.11 through 810.15.

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Article 810 Part II Receiving Equipment – Antenna Systems

- 810.11 Materials

810.11 Material. Antennas and lead-in conductors shall be of hard-drawn copper, bronze, aluminum alloy, copper-clad steel, or other high-strength, corrosion-resistant material.

Exception: Soft-drawn or medium-drawn copper shall be permitted for lead-in conductors where the maximum span between points of support is less than 11 m (35 ft).

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Copper Wire

Southwire - Bare Copper

Size (AWG)	Weight Per 1000 ft. (lbs.)	Diameter (mils)	Circular Mil Area (cmils)	Hard-Drawn		Medium-Hard Drawn		Soft-Drawn (Annealed)		Allowable Ampacity+
				Rated Strength (lbs.)	DC Resistance Ohms/1000 ft. @ 20°C	Rated Strength (lbs.)	DC Resistance Ohms/1000 ft. @ 20°C	Rated Strength (lbs.)	DC Resistance Ohms/1000 ft. @ 20°C	
SOLID										
14	12.4	64.1	4110	213.5	2.626	166.6	2.613	124.2	2.525	--
13	15.7	72	5180	268.0	2.083	208.8	2.072	156.6	2.003	--
12	19.8	80.8	6530	336.9	1.652	261.2	1.643	197.5	1.588	--
11	24.9	90.7	8230	422.9	1.310	327.6	1.303	249.0	1.260	--
10	31.4	101.9	10380	529.2	1.039	410.4	1.033	314.0	.999	--
9	39.6	114.4	13090	661.2	.824	514.2	.820	380.5	.792	--
8	50	128.5	16510	826.0	.653	643.9	.650	479.8	.628	95
7	63	144.3	20820	1030.0	.518	806.6	.515	605.0	.498	105
6	79.4	162	26240	1280.0	.411	1010.0	.409	762.9	.395	125
5	100.2	181.9	33090	1591.0	.326	1265.0	.324	961.9	.313	145
4	126.3	204.3	41740	1970.0	.258	1584.0	.257	1213.0	.249	170
3	159.3	229.4	52620	2439.0	.205	1984.0	.204	1530.0	.197	195
2	200.9	257.6	66360	3003.0	.163	2450.0	.162	1929.0	.156	225
1	253.3	289.3	83690	3688.0	.129	3024.0	.128	2432.0	.124	260

+ Ampacity based on 75°C conductor temperature; 25°C ambient temperature; 2 ft./sec. wind in sun.

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Copper Wire

Size (AWG)	Weight Per 1000 ft. (lbs.)	Diameter (mils)	Circular Mil Area (cmils)	Hard-Drawn		Medium-Hard Drawn		Soft-Drawn (Annealed)	
				Rated Strength (lbs.)	DC Resistance Ohms/1000 ft. @ 20°C	Rated Strength (lbs.)	DC Resistance Ohms/1000 ft. @ 20°C	Rated Strength (lbs.)	DC Resistance Ohms/1000 ft. @ 20°C
SOLID									
14	12.4	64.1	4110	213.5	2.626	166.6	2.613	124.2	2.525
13	15.7	72	5180	268.0	2.083	208.8	2.072	156.6	2.003
12	19.8	80.8	6530	336.9	1.652	261.2	1.643	197.5	1.588
11	24.9	90.7	8230	422.9	1.310	327.6	1.303	249.0	1.260
10	31.4	101.9	10380	529.2	1.039	410.4	1.033	314.0	.999

336 Lbs

261 Lbs

197 Lbs

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Article 810 Part II Receiving Equipment – Antenna Systems

- 810.12 Supports
  - Securely support the antenna and lead-in conductors
  - Do not attach to the electrical service mast.
  - Do not attach to poles or structures carrying open electrical light wires, power wires, trolley wires or over 250volts between conductors.
  - Lead-insulators need to be strong enough to safely support the conductors
  - Securely attach the lead-in conductors to the antenna.

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Article 810 Part II Receiving Equipment – Antenna Systems

Do not attach to a Utility pole.

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Article 810 Part II Receiving Equipment – Antenna Systems

- 810.13 Avoidance with Conductors of other systems
  - Avoid crossing conductors of power circuits to prevent accidental contact.
  - When it cannot be avoided, a 2 foot minimum is required.
  - Where practicable, the antenna conductors should not cross under open electric light or power conductors.
- 810.14 Splices
  - Make good splices that won't weaken the conductors or use approved splicing devices.

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Article 810 Part II Receiving Equipment – Antenna Systems

- 810.15 Grounding
  - Masts and metal structures supporting antennas shall be grounded in accordance with 810.21.
- 810.21Bonding Conductors & Electrodes
  - (A) Materials
  - (B) Insulation
  - (C) Supports
  - (D) Mechanical Protection
  - (E) Run in a Straight Line
  - (F) Electrode (Intersystem Bonding, Buildings with a Ground, Building without)
  - (G) Inside or Outside Building.

Grounding will be discussed in more detail.

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Article 810 Part III Amateur Transmitting and Receiving Stations – Antenna Systems.

- 810.52 Size of Antenna
- 810.53 Size of Lead-in Conductors

810.52 Size of Antenna. Antenna conductors for transmitting and receiving stations shall be of a size not less than given in Table 810.52.

Table 810.52 Size of Outdoor Antenna Conductors

Material	Minimum Size of Conductors (AWG) Where Maximum Open Span Length Is	
	Less Than 45 m (150 ft)	Over 45 m (150 ft)
Hard-drawn copper	14	10
Copper-clad steel, bronze, or other high-strength material	14	12

810.53 Size of Lead-in Conductors. Lead-in conductors for transmitting stations shall, for various maximum span lengths, be of a size at least as great as that of conductors for antennas as specified in 810.52.

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Article 810 Part III Amateur Transmitting and Receiving Stations – Antenna Systems.

ALPHA DELTA COMMUNICATIONS, INC.

Home | Photos of the Model DX-EE/DX-CC type parallel dipoles | Price List

Limited Space High Performance Antennas

Unlike the usual trap antenna, there are no capacitors to break down under high RF voltages. "ISO-RES" inductors & 12 ga. insulated solid copper wire tolerate full-legal power. 50 Ohm direct coax feed; tuner usually not required when operating in resonant bands, but may be used for multi-band.

Model DX-CC multi-band 80-10 meter dipole

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Article 810 Part III Amateur Transmitting and Receiving Stations – Antenna Systems.

- 810.54 Clearance on Buildings

810.54 Clearance on Building. Antenna conductors for transmitting stations, attached to buildings, shall be firmly mounted at least 75 mm (3 in.) clear of the surface of the building on nonabsorbent insulating supports, such as treated pins or brackets equipped with insulators having not less than 75-mm (3-in.) creepage and airgap distances. Lead-in conductors attached to buildings shall also comply with these requirements.

Exception: Where the lead-in conductors are enclosed in a continuous metallic shield that is grounded with a conductor in accordance with 810.58, they shall not be required to comply with these requirements. Where grounded, the metallic shield shall also be permitted to be used as a conductor.

This describes a piece of Coax

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Article 810 Part III Amateur Transmitting and Receiving Stations – Antenna Systems.

Minimum 3 inch clearance from RF conductor to structure.

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Article 810 Part III Amateur Transmitting and Receiving Stations – Antenna Systems.

- 810.55 Entrance to Building

- 810.56 Protection Against Accidental Contact

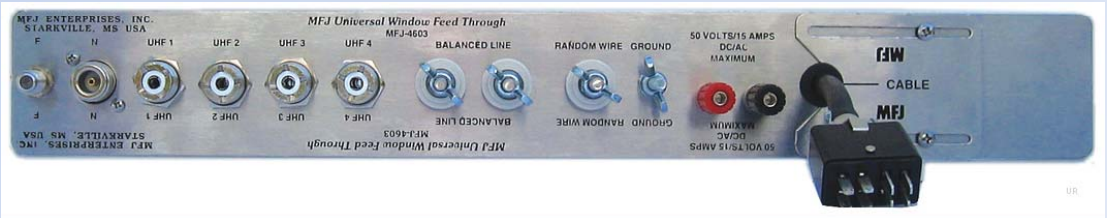
810.55 Entrance to Building. Except where protected with a continuous metallic shield that is grounded with a conductor in accordance with 810.58, lead-in conductors for transmitting stations shall enter buildings by one of the following methods:

(1) Through a rigid, noncombustible, nonabsorbent insulating tube or bushing

(2) Through an opening provided for the purpose in which the entrance conductors are firmly secured so as to provide a clearance of at least 50 mm (2 in.)

(3) Through a drilled window pane

810.56 Protection Against Accidental Contact. Lead-in conductors to radio transmitters shall be located or installed so as to make accidental contact with them difficult.



Article 810 Part III Amateur Transmitting and Receiving Stations – Antenna Systems.

- 810.57 Antenna Discharge Units – Transmitting Stations

810.57 Antenna Discharge Units — Transmitting Stations. Each conductor of a lead-in for outdoor antennas shall be provided with an antenna discharge unit or other suitable means that drain static charges from the antenna system.

Exception No. 1: Where the lead-in is protected by a continuous metallic shield that is grounded with a conductor in accordance with 810.58, an antenna discharge unit or other suitable means shall not be required.

Exception No. 2: Where the antenna is grounded with a conductor in accordance with 810.58, an antenna discharge unit or other suitable means shall not be required.

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Article 810 Part III Amateur Transmitting and Receiving Stations – Antenna Systems.

- 810.58 Bonding Conductors and Grounding Electrode Conductors
- Note: 810.21 (A) through (K) called out again.

810.58 Bonding Conductors and Grounding Electrode Conductors — Amateur and Citizen Band Transmitting and Receiving Stations. Bonding conductors and grounding electrode conductors shall comply with 810.58(A) through (C).

(A) Other Sections. All bonding conductors and grounding electrode conductors for amateur and citizen band transmitting and receiving stations shall comply with 810.21(A) through (K).

(B) Size of Protective Bonding Conductor or Grounding Electrode Conductor. The protective bonding conductor or grounding electrode conductor for transmitting stations shall be as large as the lead-in but not smaller than 10 AWG copper, bronze, or copper-clad steel.

(C) Size of Operating Bonding Conductor or Grounding Electrode Conductor. The operating bonding conductor or grounding electrode conductor for transmitting stations shall not be less than 14 AWG copper or its equivalent.

Article 810 Part III Amateur Transmitting and Receiving Stations – Antenna Systems.

- 810.21Bonding Conductors & Electrodes
  - (A) Materials
  - (B) Insulation
  - (C) Supports
  - (D) Mechanical Protection
  - (E) Run in a Straight Line
  - (F) Electrode (Intersystem Bonding, Buildings with a Ground, Building without)
  - (G) Inside or Outside Building.

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Article 810 Part III Amateur Transmitting and Receiving Stations – Antenna Systems.

- 810.21Bonding Conductors & Electrodes

(A) Material. The bonding conductor or grounding electrode conductor shall be of copper, aluminum, copper-clad steel, bronze, or similar corrosion-resistant material. Aluminum or copper-clad aluminum bonding conductors or grounding electrode conductors shall not be used where in direct contact with masonry or the earth or where subject to corrosive conditions. Where used outside, aluminum or copper-clad aluminum conductors shall not be installed within 450 mm (18 in.) of the earth.

(B) Insulation. Insulation on bonding conductors or grounding electrode conductors shall not be required.

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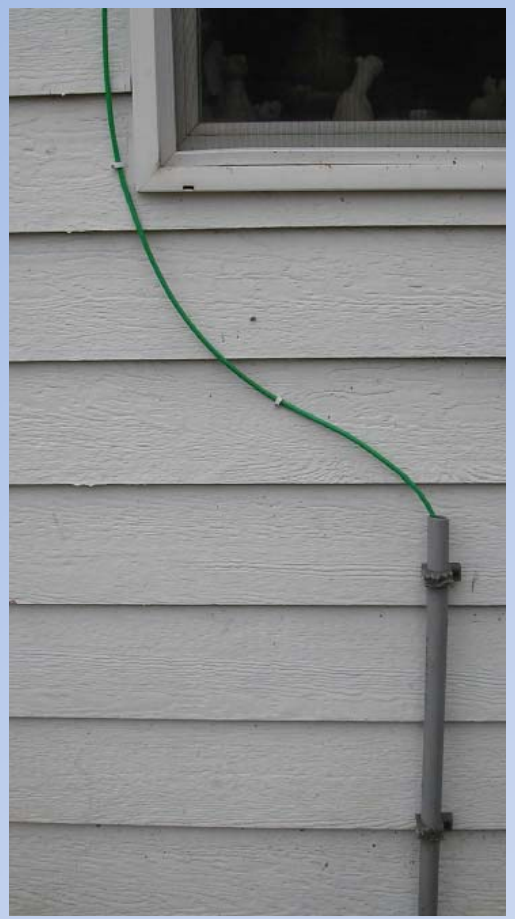
Article 810 Part III Amateur Transmitting and Receiving Stations – Antenna Systems.

- 810.21Bonding Conductors & Electrodes



(C) Supports. The bonding conductors and grounding electrode conductors shall be securely fastened in place and shall be permitted to be directly attached to the surface wired over without the use of insulating supports.

Exception: Where proper support cannot be provided, the size of the bonding conductors and grounding electrode conductors shall be increased proportionately.

(D) Mechanical Protection. The bonding conductors and grounding electrode conductor shall be protected where exposed to physical damage. Where the bonding conductor or grounding electrode conductor is run in a metal raceway, both ends of the raceway shall be bonded to the contained conductor or to the same terminal or electrode to which the conductor is connected.

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Article 810 Part III Amateur Transmitting and Receiving Stations – Antenna Systems.

- 810.21Bonding Conductors & Electrodes

(E) Run in Straight Line. The bonding conductor or grounding electrode conductor for an antenna mast or antenna discharge unit shall be run in as straight a line as practicable.

  - (F) Electrode
    - (1) In Building with an Intersystem Bonding Termination
    - (2) In Building with a Grounding Means
    - (3) In Building without and Intersystem Bonding Termination or a Grounding Means

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Article 810 Part III Amateur Transmitting and Receiving Stations – Antenna Systems.

- 810.21Bonding Conductors & Electrodes

(F) Electrode. The bonding conductor or grounding electrode conductor shall be connected as required in (F)(1) through (F)(3).

(1) In Buildings or Structures with an Intersystem Bonding Termination. If the building or structure served has an intersystem bonding termination as required by 250.94, the bonding conductor shall be connected to the intersystem bonding termination.

Informational Note: See Article 100 for the definition of *Intersystem Bonding Termination.*

Intersystem Bonding Termination. A device that provides a means for connecting communications system(s) grounding conductor(s) and bonding conductor(s) at the service equipment or at the disconnecting means for buildings or structures supplied by a feeder or branch circuit.

Article 810 Part III Amateur Transmitting and Receiving Stations – Antenna Systems.

- Intersystem Bonding Termination

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Article 810 Part III Amateur Transmitting and Receiving Stations – Antenna Systems.

Intersystem Bonding Termination

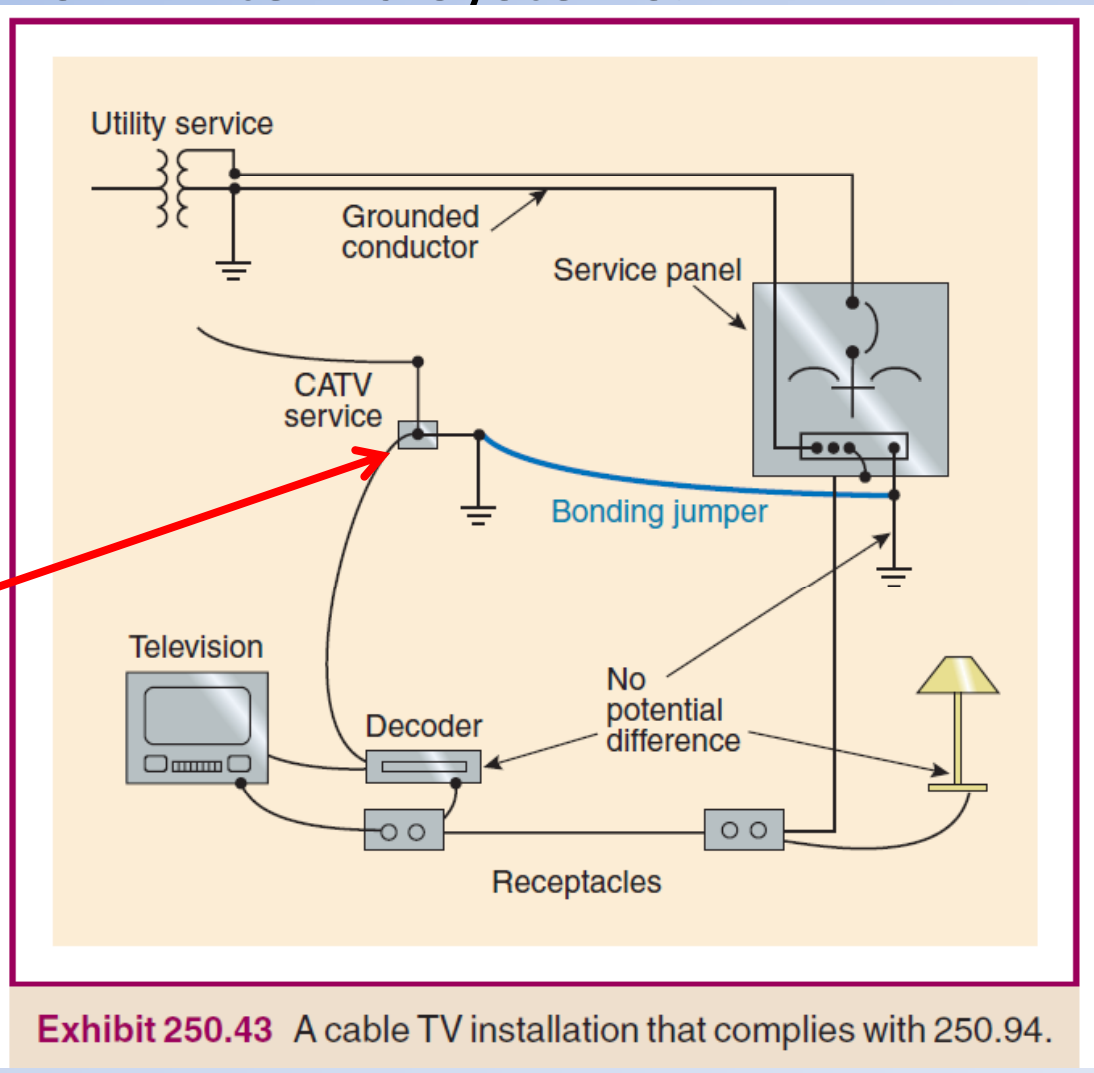
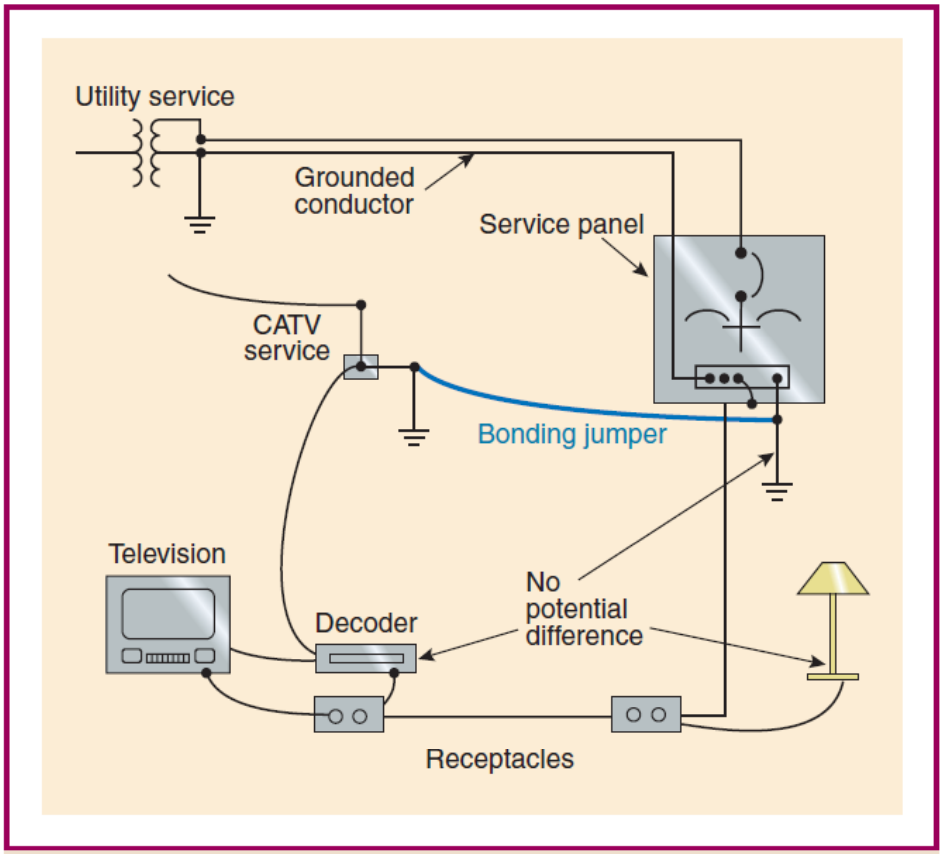


Exhibit 250.43 A cable TV installation that complies with 250.94.

Grounding and Bonding – Article 250.94 Bonding for Other Systems



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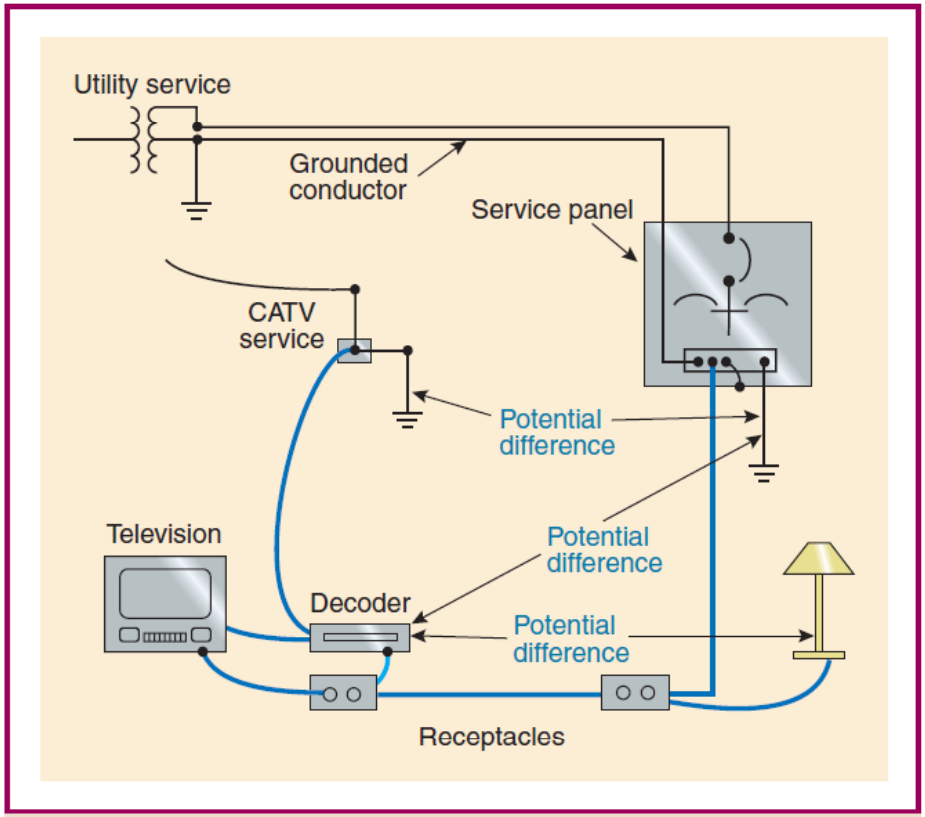

Exhibit 250.42 A CATV installation that does not comply with the *Code*, illustrating why bonding between different systems is necessary.

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Article 810 Part III Amateur Transmitting and Receiving Stations – Antenna Systems.

- 810.21Bonding Conductors & Electrodes

(2) In Buildings or Structures with Grounding Means. If the building or structure served has no intersystem bonding termination, the bonding conductor or grounding electrode conductor shall be connected to the nearest accessible location on the following:

(1) The building or structure grounding electrode system as covered in 250.50

(2) The grounded interior metal water piping systems, within 1.52 m (5 ft) from its point of entrance to the building, as covered in 250.52

(3) The power service accessible means external to the building, as covered in 250.94

(4) The nonflexible metallic power service raceway

(5) The service equipment enclosure, or

(6) The grounding electrode conductor or the grounding electrode conductor metal enclosures of the power service

Article 810 Part III Amateur Transmitting and Receiving Stations – Antenna Systems.

- 810.21Bonding Conductors & Electrodes

(3) In Buildings or Structures Without an Intersystem Bonding Termination or Grounding Means. If the building or structure served has no intersystem bonding termination or grounding means as described in 810.21(F)(2), the grounding electrode conductor shall be connected to an electrode as described in 250.52.

(G) Inside or Outside Building. The bonding conductor or grounding electrode conductor shall be permitted to be run either inside or outside the building.

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Article 810 Part III Amateur Transmitting and Receiving Stations – Antenna Systems.

- 810.21Bonding Conductors & Electrodes

(H) Size. The bonding conductor or grounding electrode conductor shall not be smaller than 10 AWG copper, 8 AWG aluminum, or 17 AWG copper-clad steel or bronze.

(I) Common Ground. A single bonding conductor or grounding electrode conductor shall be permitted for both protective and operating purposes.

(J) Bonding of Electrodes. A bonding jumper not smaller than 6 AWG copper or equivalent shall be connected between the radio and television equipment grounding electrode and the power grounding electrode system at the building or structure served where separate electrodes are used.

(K) Electrode Connection. Connections to grounding electrodes shall comply with 250.70.

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Article 810 Part III Amateur Transmitting and Receiving Stations – Antenna Systems.

No Ground Connection for the radio or amp shown in this figure.

(H) 10 AWG Copper

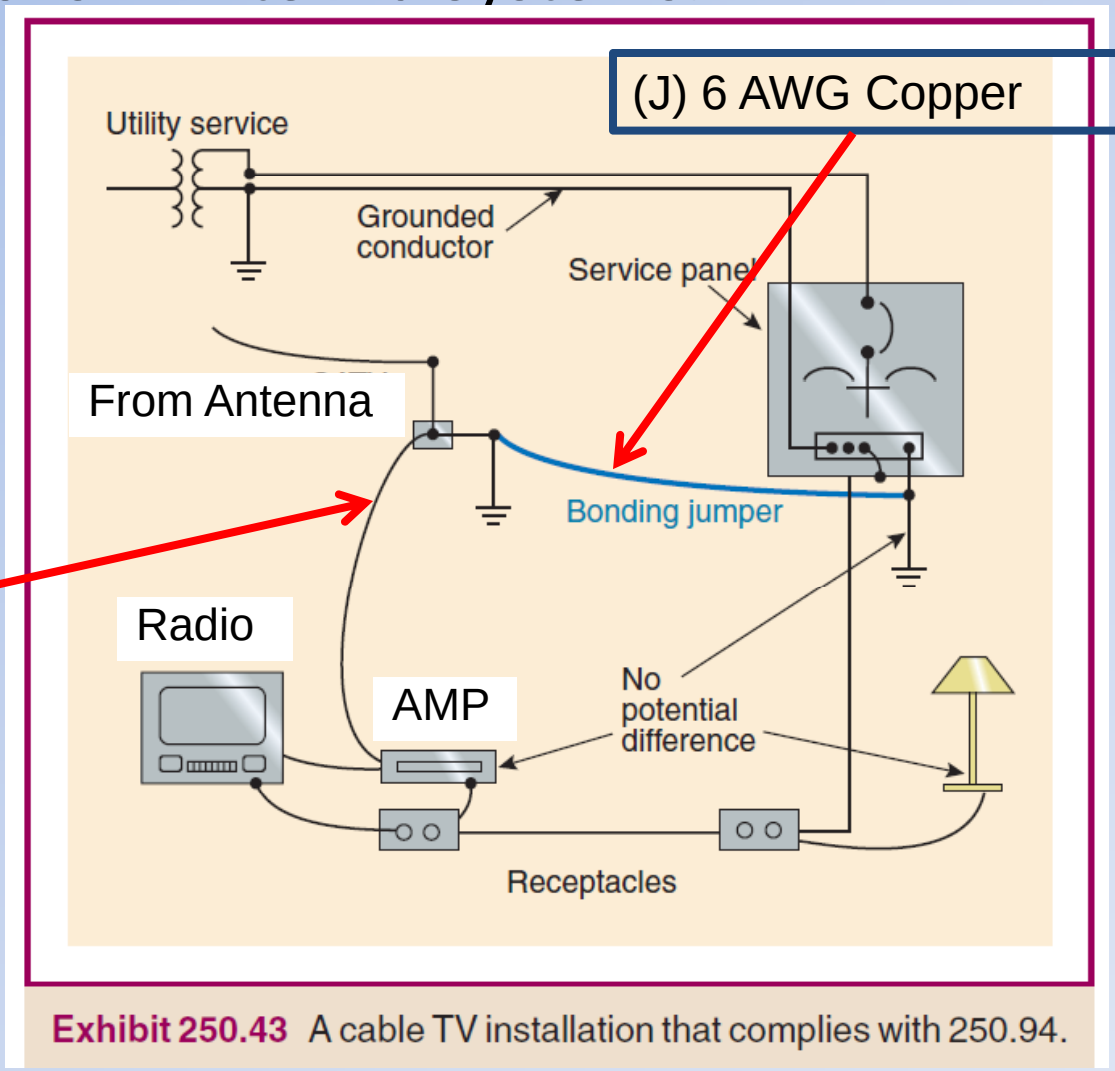

Exhibit 250.43 A cable TV installation that complies with 250.94.

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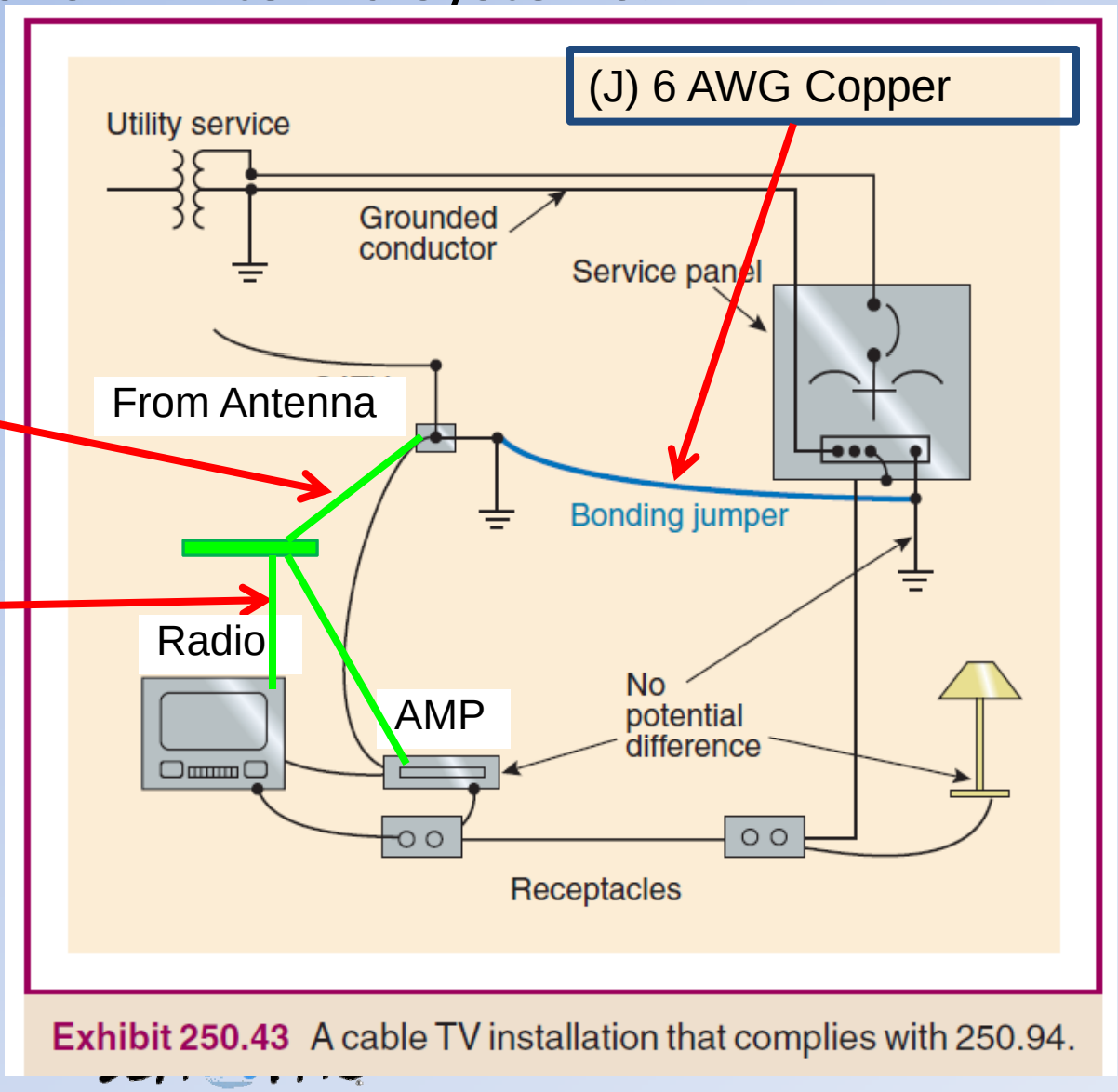
Article 810 Part III Amateur Transmitting and Receiving Stations – Antenna Systems.

(I) Common Protective and Operating Ground

(H) 10 AWG Copper



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Article 810 General Part 1

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    - Coaxial cables that connect antennas to equipment shall comply with Article 820 (Community Antenna Television & Radio Distribution Systems).

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Article 820 CATV and Radio Distribution Systems – As it Applies to Coax.

- We will only review items that are specific to Coax and that wasn't covered by the other sections for Residential Installations.

- 820.2 Definitions

Coaxial Cable. A cylindrical assembly composed of a conductor centered inside a metallic tube or shield, separated by a dielectric material, and usually covered by an insulating jacket.

820.15 Power Limitations. Coaxial cable shall be permitted to deliver power to equipment that is directly associated with the radio frequency distribution system if the voltage is not over 60 volts and if the current is supplied by a transformer or other device that has power-limiting characteristics.

Power shall be blocked from premises devices on the network that are not intended to be powered via the coaxial cable.

Article 820 CATV and Radio Distribution Systems – As it Applies to Coax.

820.24 Mechanical Execution of Work. Community television and radio distribution systems shall be installed in a neat and workmanlike manner. Coaxial cables installed exposed on the surface of ceiling and sidewalls shall be supported by the building structure in such a manner that the cables will not be damaged by normal building use. Such cables shall be secured by hardware including straps, staples, cable ties, hangers, or similar fittings designed and installed so as not to damage the cable. The installation shall also conform to 300.4(D) and 300.11.

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Article 820 CATV and Radio Distribution Systems – As it Applies to Coax.

- Aerial Cable Summary
  - Where practical, locate the coax cable below the power cable.
  - Keep coax away to avoid accidental contact with power and lighting.
  - Cable passing above a roof require 8 feet of clearance from all points of the roof.
  - On buildings:
    - Separate from power or lighting by 4 inches
    - Separate from Communications to avoid interference for maintenance and to avoid abrasion.
    - Where practical, separate from lightning conductors by 6 feet.

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Article 820 CATV and Radio Distribution Systems – As it Applies to Coax.

- Underground Summary
  - Underground coax in ducts, manholes or pedestals need to be separated by a permanent suitable separator.
  - Direct Buried coax cables shall be separated by 12 inches from power and lighting.
- Unlisted cables can be routed in a building up to 50 feet from the point of entrance. Transition to a listed cable after 50 feet.

SEAPAC

Article 820 CATV and Radio Distribution Systems – As it Applies to Coax.

III. Protection

820.93 Grounding of the Outer Conductive Shield of Coaxial Cables. Coaxial cables entering buildings or attached to buildings shall comply with 820.93(A) or (B). Where the outer conductive shield of a coaxial cable is grounded, no other protective devices shall be required. For purposes of this section, grounding located at mobile home service equipment located within 9.0 m (30 ft) of the exterior wall of the mobile home it serves, or at a mobile home disconnecting means grounded in accordance with 250.32 and located within 9.0 m (30 ft) of the exterior wall of the mobile home it serves, shall be considered to meet the requirements of this section.

SEAPAC

Article 820 CATV and Radio Distribution Systems – As it Applies to Coax.

- Grounding and Bonding
  - Same requirements in Article 820 as outlined in Article 810
  - In buildings with an intersystem bonding terminator, connect to it.
  - In buildings with a grounding means, connect to it.
  - In buildings without an intersystem bonding terminator or a grounding means, provide a ground electrode.

SEAPAC

Article 820 CATV and Radio Distribution Systems – As it Applies to Coax.

- There is a lot more information in 820 dealing with coax inside buildings that may be more applicable to commercial buildings than a private residence.
- If you provide consulting for an amateur station in a commercial or public buildings the remaining articles need to be reviewed and applied.

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The End
Questions ?

Tim Kuhlman – KD7RUS
Email: tim.kuhlman@ch2m.com

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