

# Antenna System Bonding and Grounding Requirements in the USA

Whitham D. Reeve (© 2012 W. Reeve)

## Introduction

Voltages and currents caused by lightning, power cross and electrostatic charge buildup on antenna systems can present a significant safety hazard in radio telescope installations, possibly leading to electrocution and fire. These hazards can be reduced by proper bonding, grounding and surge protection.

### Abbreviations

ADU	Antenna Discharge Unit
ARRL	American Radio Relay League
AWG	American Wire Gauge
HF	High Frequency
NEC	National Electrical Code
NFPA	National Fire Protection Association
VHF	Very High Frequency

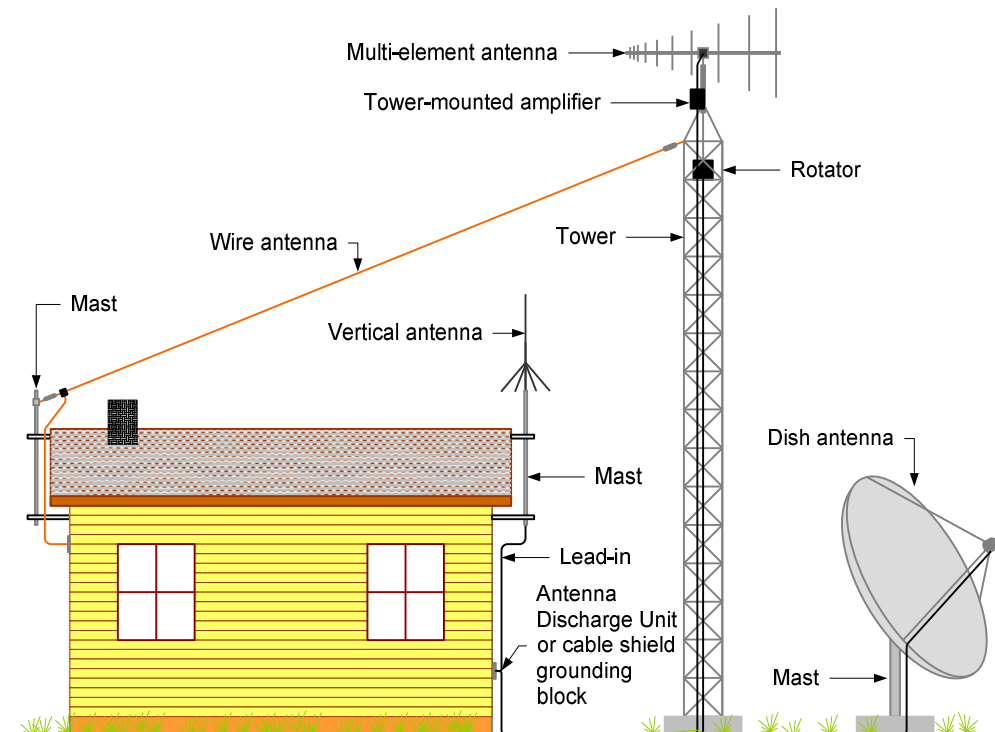


In most of the United States, the *National Electrical Code* (NEC) is used to specify the installation requirements for outdoor antenna systems.[1] The NEC is not a design specification, and it does not address anything having to do with radio propagation, structural requirements or the actual use of radio telescopes. There is no requirement that the antenna system actually work, only that it be safe. The NEC is a set of minimum requirements *for the practical safeguarding of persons and property from hazards arising from the use of electricity* [par. 90.1(A)]. The requirements in other countries may differ from the NEC.

Many people think they are immune from the requirements of the NEC or that it does not apply to them. On the contrary, adoption of the NEC by government jurisdictions – cities, counties and states – requires that it be properly applied to any installation within that jurisdiction regardless of the property owner’s thoughts on the matter.

I will discuss the NEC bonding and grounding requirements that apply to radio telescope installations. These are called “*Receiving Stations*” in the NEC. In particular, NEC article 810, *Radio and Television Equipment*, in chapter 8, *Communications Systems*, specifies the requirements for installation of outdoor antennas, antenna support structures (towers and masts) and the wiring and cabling that are used to connect them to radio equipment (figure 1). Article 810 refers to article 250, *Grounding and Bonding*, so I also will discuss its associated requirements.

Fig. 1 – Various types of antenna systems. The National Electrical Code covers the aspects of antenna system installations that pertain to electrical safety



## NEC Article 810

Article 810 applies to radio and television receiving equipment and amateur and citizen band transmitters and receivers as well as wire, multi-element, vertical rod and dish antennas and the wiring and cabling for powering and controlling tower- and mast-mounted equipment (for example, preamplifiers and rotators). I will primarily discuss [par. 810.20] and [par. 810.21] in article 810 (brackets will be used to indicate NEC paragraph numbers throughout this article). These paragraphs cover antenna discharge units, lead-ins and bonding and grounding electrode conductors for antenna masts and towers. I note that some radio astronomers also are radio amateurs and use transmitting equipment. The NEC includes specific requirements starting at [par. 810.51] for transmitting equipment and associated antennas. These and other paragraphs in article 810 are beyond the scope of this article.

In spite of its importance, the NEC historically has been considered a poorly written document, full of jargon and requirements that favored certain manufacturers. The inability of ordinary people to correctly interpret the NEC's often-times confusing language is why many installations do not comply with it. Even after all the years of working with the NEC, I still am amazed how confusing it can be and how difficult it is to properly apply.

Vast readability improvements have been made to the NEC over the last decade. Most of the region-specific trade jargon has been removed, making it much easier to read and understand. I hope this article helps you, but nothing in here constitutes engineering advice. At the time of this writing, the current NEC is the 2011 edition (the next edition will be in 2014). While reading this article do not attempt to follow by using an earlier edition because there have been many changes that appear only in the current (2011) edition.

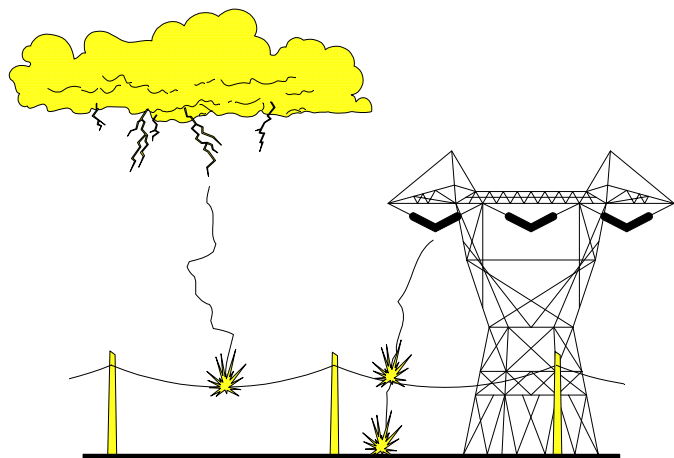
The NEC is published by National Fire Protection Association (NFPA) and sold online as well in bookstores for around US\$70 or more. It may be viewed online for free at <http://www.nfpa.org/aboutthecodes/aboutthecodes.asp?docnum=70>. Readers may wish to go there at this time so they can follow along as I discuss the various requirements (free registration is required).

### Exposure

Outdoor antennas, particularly those mounted on towers and masts, are considered to be exposed to lightning and static buildup (figure 2). There also is the possibility of powerline contact during erection and use if the antennas or towers are near powerlines. Accidental powerline contact and electrocution may be a statistically more significant problem than injury or death by lightning, but lightning can lead to fires and property damage. The NEC requirements do not differentiate.

Fig. 2 – Exposure to lightning, power cross, and static buildup are hazards to radio astronomers

The probability of lightning strikes in any given area is related to the lightning flash density (flashes/km<sup>2</sup>/yr). Lightning flash density varies widely across the United States with the highest in Florida and along the coast of Louisiana. See [http://www.lightningsafety.noaa.gov/lightning\\_map.htm](http://www.lightningsafety.noaa.gov/lightning_map.htm).



A direct or nearby lightning strike, called a *lightning event*, can cause considerable damage to not only the antenna system but anything connected to it, possibly leading to shock and fire. It is impossible to prevent damage from a direct lightning strike but the chances of damage and fire caused by most other lightning events may be reduced by limiting voltages and currents on the antenna systems through the use of proper bonding, grounding and surge protection devices.

Although not specifically discussed in this article, NFPA 780, *Standard for Installation of Lightning Protection Systems*, is a worthwhile reference and includes highly detailed information.[2]

### Antenna discharge unit

The NEC requires that each lead-in conductor from an outdoor antenna be provided with a *listed* antenna discharge unit (ADU) unless the lead-in has a continuous shield that is properly grounded (figure 3) [par. 810.20(A)]. The term *lead-in* refers to any cable or conductor from the antenna system including coaxial cables, waveguides, rotator control cables, and powering conductors and cables for mast- or tower-mounted amplifiers and other outdoor electronics associated with the antenna system.

Antenna discharge units are known by many names including lightning protectors, lightning protection devices, surge arresters and surge protection devices. The term *listed* refers to products that have been evaluated and tested by an independent testing laboratory and found to be suitable for a specified purpose. Probably the most familiar testing laboratories are UL (previously Underwriter's Laboratory) and Intertek.

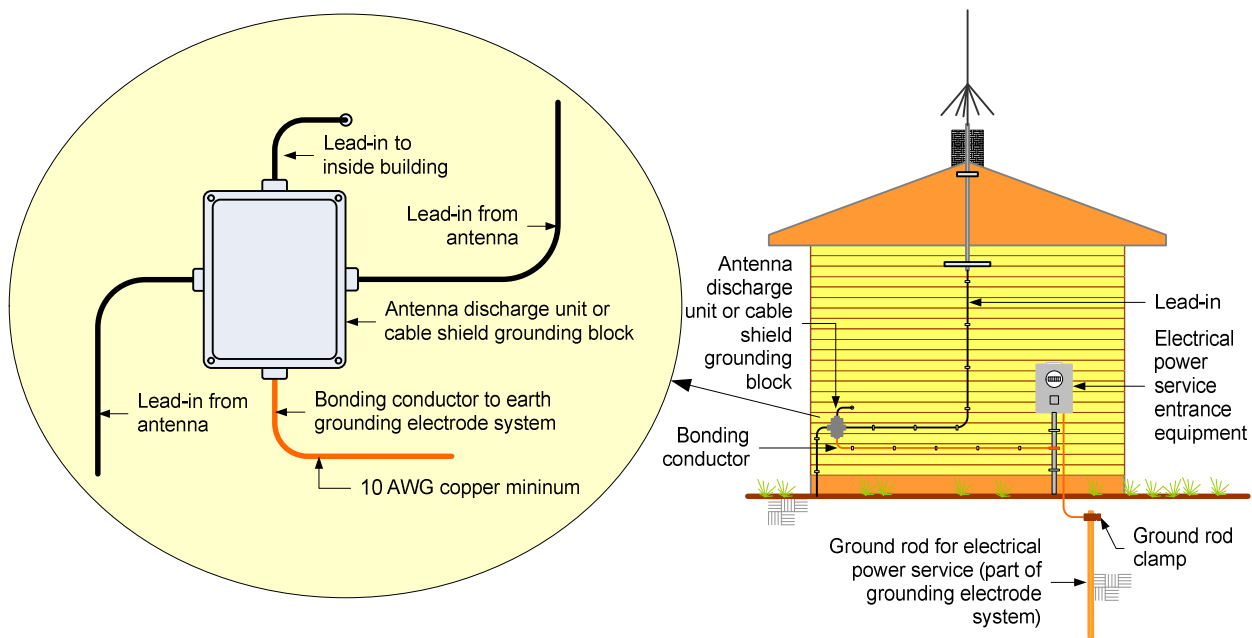


Fig. 3 – Antenna discharge unit. The antenna discharge unit protects antenna wiring and cabling from over-voltages caused by lightning, power cross and static buildup

UL standard UL 452 covers antenna discharge units. At the time of this writing (December 2011) there are only three manufacturers that make listed products (table 1). As you can see, there are no devices that have specific radio astronomy (or even radio amateur) application. This certainly limits your alternatives for compliance with the NEC.

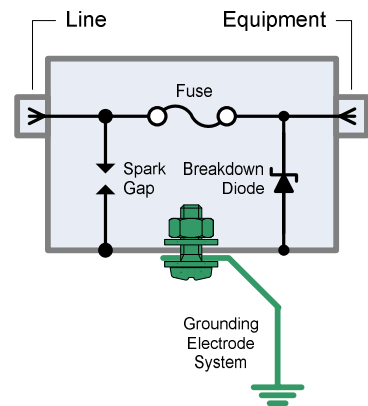
Table 1 – UL 452 listed antenna discharge units

Manufacturer	Model number	Remarks
Radio Systems Corp.	LP3000	Designed for use with invisible dog fences
Leviton	5350-SAT	Designed for coaxial cable but is equipped with F connectors, 1.5 GHz maximum
Leviton	5350-PC	Similar to –SAT but plugs into ac receptacle for grounding, 1 GHz maximum
Global Communications Ltd	DPP33	Designed for switching coaxial cables from three satellite dishes to three receivers and is equipped with F connectors
Global Communications Ltd	DPP44	Similar to DPP33 but for four dishes and receivers

It should be noted that some manufacturers of coaxial lightning protection devices (for example, Polyphaser, Altelicon, and Terrawave) make products that serve the purpose of antenna discharge units but are not listed as such and, therefore, are not compliant with the NEC in this regard. An acceptable alternative to the antenna discharge unit – bonding and grounding of cable shields – is discussed in the next section. For completeness, the following information on antenna discharge units will help you understand the requirements and possibly find something that will work for your installation.

An antenna discharge unit consists of an arc-gap (spark-gap), a fixed resistance or discharge element, or a combination, that is connected between each lead-in terminal and a grounding terminal. Antenna discharge units are voltage limitation devices (figure 4).

Fig. 4 – Schematic of an antenna discharge unit for wire conductors. This unit provides both voltage limitation (transient voltage suppression or breakdown diode and spark-gap) and current limitation (fuse)



During a voltage surge caused by a lightning event, accidental power contact (power cross) or static buildup caused by wind or blowing snow, the ADU clamps the voltage on the lead-in to some maximum value (typical values range from 90 to 240 V) and diverts the resulting current to earth ground via the bonding and grounding electrode conductors. The energy associated with the voltage and current is then safely dissipated in the earth. The actual voltage clamping device often is a gas-tube element (figure 5).

Antenna discharge units usually are located outside the building. They may be located inside the building at the point of entrance of the lead-in but not near combustible material [par. 810.20(B)]. Finally, the ADU must be grounded [par. 810.20(C)]. Additional details are provided after the next section.

Fig. 5 – Antenna discharge unit for coaxial cable with type N connectors and a replaceable gas-tube element. The gas-tube element has been removed and is the small cylinder just above the main body and below the spring and cap. When the voltage across the gas-tube reaches its threshold value, the gas inside the element conducts. The resulting current is diverted to earth ground where it is safely dissipated. The screw for connection of the bonding conductor is on the bottom of the body. This type of arrestor device has redundant features with respect to the NEC – voltage limitation of the antenna discharge unit and shield grounding. This device is shown for illustration of concepts and is not listed in UL 452



## Alternative to antenna discharge unit

An acceptable alternative to an antenna discharge unit is to use shielded cables for all lead-ins and to ensure the shields are properly grounded [par. 810.20(A) Exception]. Given that there presently are no listed ADUs, this alternative becomes your only choice in the context of the NEC. Coaxial cable shields may be bonded using a cable shield grounding block (figure 6). Grounding blocks are available only with 75 ohm F-connectors (designed for cable and satellite television) so are not suitable where it is necessary to pay close attention to signal reflection on 50 ohm coaxial cables. Generally, in most amateur radio astronomy applications at HF (3 ~ 30 MHz) or lower this is not a significant problem. Many HF radio telescopes use 75 ohm cable and connectors. However, adapters for other connector types usually are needed at various interfaces.



Fig. 6 – Cable shield grounding block (right). The grounding block shown is the type commonly used with cable television and satellite dish antennas that have F connectors

At higher frequencies, VHF and above, impedance matching needs more careful attention. Radio telescope equipment and coaxial cables often are based on 50 ohms impedance. The 75 ohm type F connectors on grounding blocks may impose an unacceptable impedance mismatch.

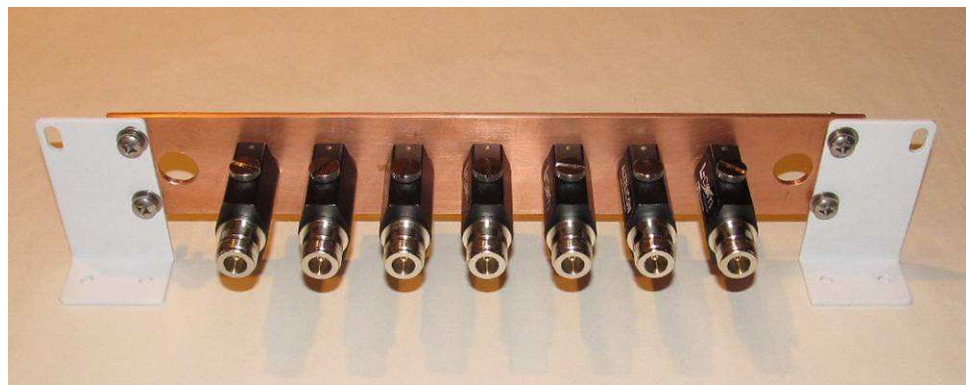
Where the type F connector grounding blocks will not work, coaxial cable shield grounding clamps or straps may be used (figure 7). These are available from major coaxial cable manufacturers, such as Times Microwave, Commscope (Andrew), Terrawave and their suppliers. Another alternative is to use a copper busbar with coaxial feed-through type bulkhead connectors or coaxial lightning arrestors (figure 8).

Because antenna discharge units are not available for radio applications covered by this article, it also is necessary to use shielded power and control cables for tower- and mast-mounted equipment. A continuous metal conduit or raceway system that completely encloses the cable could be used for this purpose but may be expensive and difficult to build. Therefore, the practical solution is to use ordinary shielded cables and to bond the shields using methods similar to coaxial cables, such as a bonding clamp described previously or the so-called “bullet bond” commonly used on shielded telecommunications cables (figure 9).



Fig. 7 – Coaxial cable bonding clamp (right). Bonding clamps usually cover a range of coaxial cable diameters. The cable jacket is carefully cut away to expose the shield. The preformed copper strap (lower-left corner of photo) is installed over the shield, sealed with the included mastic tape (upper) and then bonded to the earth electrode system using the wire provided. This particular kit costs about US\$35 and is used with LMR400 coaxial cable. Less expensive kits are available for about US\$10 that loop around and then clamp the exposed cable shield

Fig. 8 – Coaxial cable shield bonding bar and lightning protection assembly. The 2 in x 12 in x 1/8 in copper bar was purchased from an auction website. Holes for nine lightning arrestors were cut, and seven were installed. The brackets at each end were recycled from



old equipment. The lightning arrestors shown use type N connectors and provide the means to bond the cable shields to ground

Fig. 9 – Shield bond connector (also called “bullet-bond”). Variations of these are available for use with different cable diameters. The two pieces are slipped between the cable jacket and shield and between the shield and cable core and then are clamped with one nut. The other nut holds the ring lug on the bonding conductor



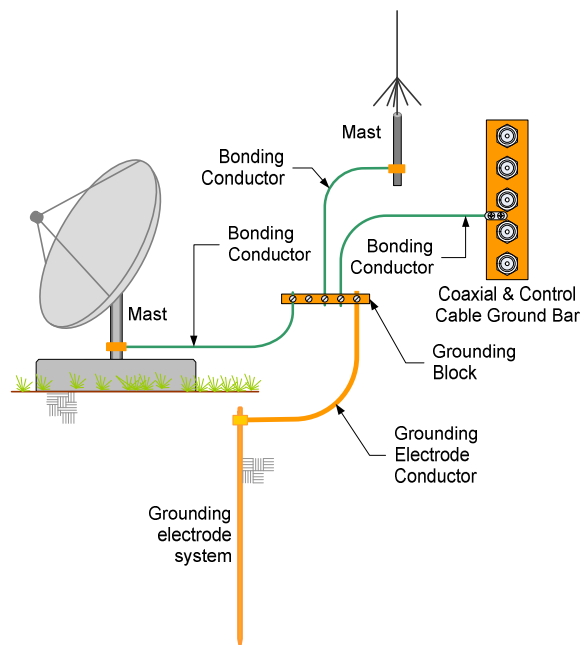
Before going to the next section, I should mention a problem with the American Radio Relay League (ARRL) Handbook for Radio Communications.[3] Normally this handbook is a good resource for safety information related to radio. However, the discussions in chapter 28, *Safety*, of the 2012 handbook on NEC requirements for lead-ins and antenna discharge units are wrong. Details have been provided to ARRL and also are listed in the [Appendix](#) to this article.

## Bonding and grounding

Lightning, power contact and static buildup also can cause dangerous voltage levels on masts and towers and shock you if you touch them. Therefore, along with shielded cables, antenna support structures must be bonded to earth ground [par. 810.15]. The conductors for this purpose are called *bonding conductors* and *grounding electrode conductors*. The NEC differentiates between the two types of conductors because they serve different purposes (figure 10):

- A bonding conductor connects metal parts together so that the voltage differences between them are small, thus minimizing the shock hazard if you touch two metallic components that are not directly fastened together
- A grounding electrode conductor connects the bonded metal parts to a grounding electrode (commonly called earth ground) or to a point on a grounding electrode system. This provides a path for unintentional currents to the earth where the energy can be safely dissipated, thus reducing the likelihood of fire and shock by limiting the surge voltage

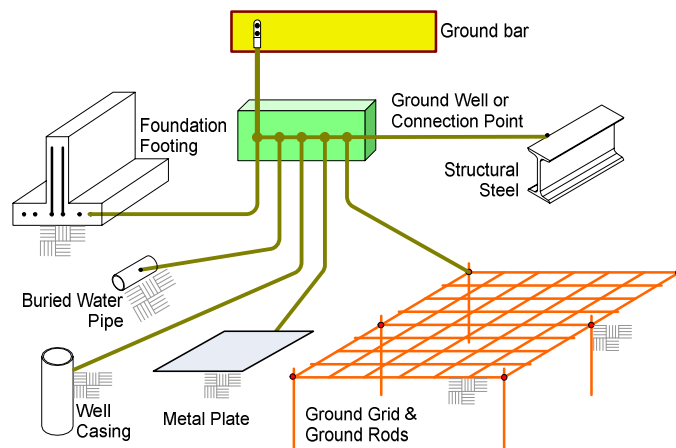
Fig. 10 – Bonding and grounding electrode conductors. Control cables and coaxial cables not shown



Grounding electrode requirements are specified in [par. 250.52] of the NEC, which is part of chapter 2, *Wiring and Protection*, article 250, *Grounding and Bonding*. The most familiar grounding electrode is the driven ground rod made from copper clad steel or galvanized steel, but there are many others such as the concrete encased electrode (so-called Ufer ground), buried metal plate, water well casing, buried metallic water pipe and buried bare wire in various ring and grid configurations (figure 11). Where more than one electrode exists, they are bonded together to form a *grounding electrode system* [article 250.50]. The last couple editions of the NEC have clarified and changed the requirements for earth electrodes compared to earlier editions. These changes are beyond the scope of this article.

The conductors used for bonding and connection to the earth grounding electrode are required to be copper, aluminum, copper-clad steel, bronze or similar corrosion resistant material [par. 810.21(A)]. Aluminum and copper-clad aluminum conductors cannot be used in direct contact with or within 450 mm of masonry or soil due to corrosion concerns. Most applications use copper or a copper alloy but

local conditions may indicate that other allowable materials are better from a corrosion standpoint. Aluminum should be avoided because long-lasting connections are difficult to make with it. Bonding and grounding conductors may be solid or stranded, and they may be bare or insulated [par. 810.21(B)]. Although not required by the NEC, corrosion inhibitor (anti-oxidant) should be used at all bonding



connections. This is especially important where stainless steel hardware is used. Burndy Penatrox and Ideal Noalox are two commonly available examples.

Figure 11 – Various types of earth grounding electrodes. Where more than one exists, they must be bonded together

Bonding and grounding conductors must be securely fastened in place and physically protected where exposed to damage [par. 810.21(C) and 810.21(D)]. The NEC does not specify fastening methods, spacing of the

fasteners or supports, or physical protection methods, leaving those decisions to the common sense of the installer. Staples, clips and cable ties with saddle mounts are some examples of fasteners that can be used for this purpose. Generally, supports are spaced no more than 3 ft or 1 m. Simply covering the conductors with small non-metallic (for example, polyvinyl chloride, PVC) conduit or routing them such that they cannot be accidentally pulled loose or broken generally is adequate protection.

If the bonding or grounding electrode conductors are installed in ferromagnetic metal raceways, such as electrical metallic tubing (EMT, also called thin-wall), intermediate metal conduit (IMC) or galvanized rigid conduit (GRC), both ends of the raceway are required to be connected to the bonding conductor or grounding electrode conductor. Bonding of both ends prevents the conductor and raceway from acting like an inductor (choke) and preventing or reducing surge current flow and allowing the voltage to rise to dangerous levels. From a practical standpoint, non-metallic conduits are a much better choice than metallic conduits for enclosing these conductors and, of course, they do not need to be bonded.

Bonding and grounding electrode conductors must be run in the straightest path possible without loops or sharp bends [par. 810.21(E)]. A straight path offers the least impedance to the passage of stroke current. Conductor bends usually are unavoidable, in which case they should have at least 200 mm radius and form an included angle less than 90 deg. It should be noted that side flash (electrical spark) is possible where the conductors pass by unrelated metal parts. This can be minimized by bonding the metal parts to the conductor.

## Terminations

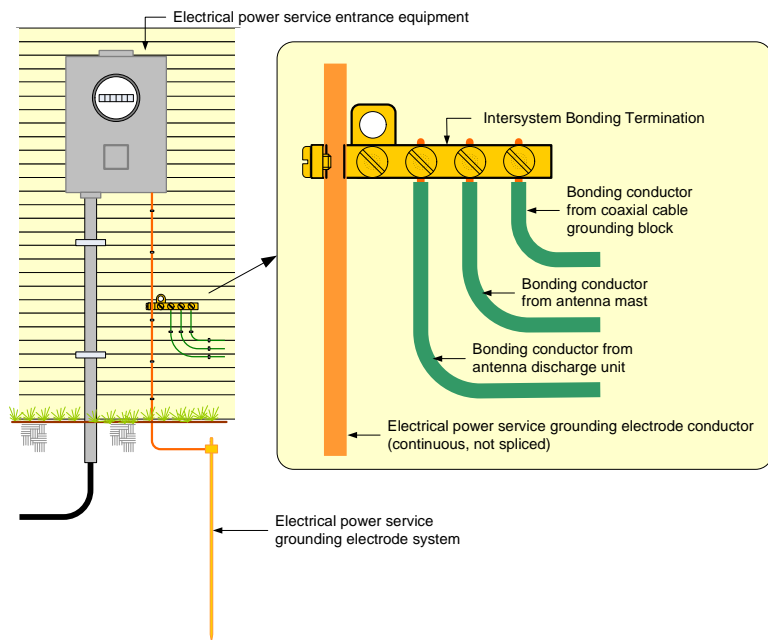
The NEC describes the requirements for connections to the earth grounding electrode in terms of three scenarios [par. 810.21(F)]

1. Locations with an existing intersystem bonding termination
2. Locations with a grounding electrode system but no intersystem bonding termination
3. Locations with neither an intersystem bonding termination nor a grounding electrode system

Scenario 1: The bonding conductors for the antenna mast or tower and antenna discharge unit must connect to an *intersystem bonding termination* if one is available [par. 810.21(F)(1)]. The intersystem bonding termination is more commonly called a *grounding bridge* or *grounding block*. It is a junction or busbar that provides a common point for connecting the bonding conductors of different systems (figure 12). For example, it interconnects the bonding and grounding conductors associated with cable

television service, regular telephone service, other broadband telecommunications services and, of course, your radio telescope antenna system to the electrical power service grounding electrode system.

Fig. 12 – Scenario 1, grounding system with existing intersystem bonding termination. The intersystem bonding termination usually is mounted in line with the electrical power service grounding conductor so that it can be connected directly to the wire. The individual bonding conductors from the various antenna systems are then connected as shown.



The intersystem bonding termination reduces the voltage differences

between the electrical power system, the various other services and radio and television antennas and supporting structures during a lightning event, thus reducing damaging current flow and the associated shock and fire hazard. It is located near the building's electrical service entrance equipment (service entrance equipment typically is a meterbase and main disconnect circuit breaker).

Generally, only newer buildings and homes will have an intersystem bonding termination but one may be retrofitted to most existing installations. The requirements for the intersystem bonding termination are specified in the NEC [par. 250.94]. Generally, it must be accessible for connection and inspection, have enough terminals to connect at least three intersystem bonding conductors and be bonded to the electrical power service grounding electrode system with a 6 AWG copper conductor.

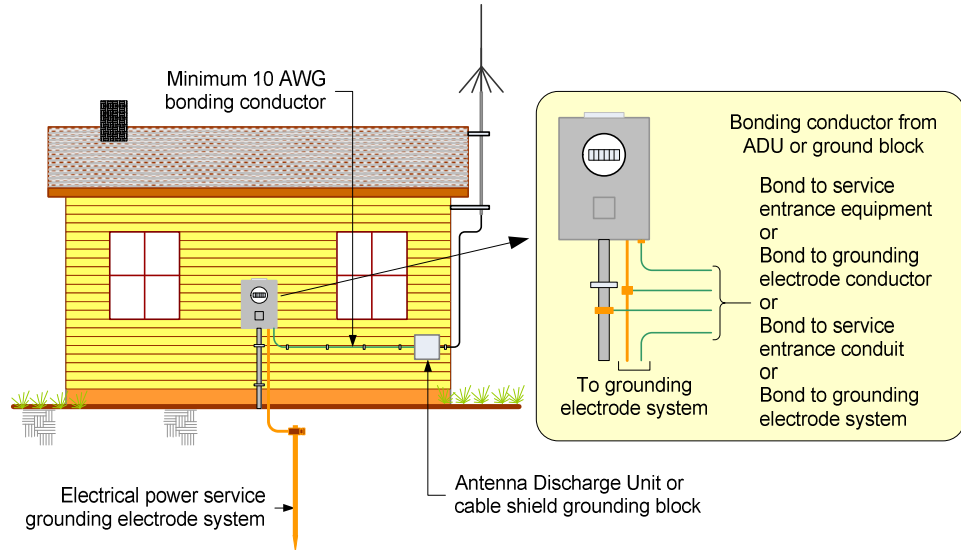
Scenario 2: Where an intersystem bonding termination is not available but the building is equipped with a grounding electrode system, it is required that the bonding conductor or grounding electrode conductor be connected to the nearest accessible location on one of the following (figure 13) [par. 810.21(F)(2)]

- Building or structure grounding electrode system, as covered in [par. 250.50]. There are many choices including metal underground water pipe, building metal frame or structure, concrete-encased electrode, ground ring, rod and pipe electrode, plate electrode and other local metal underground systems or structures. If more than one of these exists they must be bonded together
- Grounded interior metal water piping system no more than 5 ft from its point of entrance, as covered in [par. 250.52]. If used, this pipe must be in direct earth contact for at least 10 ft
- Electrical power service equipment external to the building, as covered in [par. 250.94]
- Nonflexible metallic electrical power service raceway (conduit) using a suitable clamp
- Electrical power service equipment enclosure using a suitable screw



- Grounding electrode conductor or the grounding electrode conductor metal enclosure of the electrical power service equipment

Fig. 13 – Scenario 2, grounding system without intersystem bonding termination (below). The antenna discharge unit or cable shield grounding block is bonded to the nearest accessible location of the grounding electrode system. Four common locations are shown

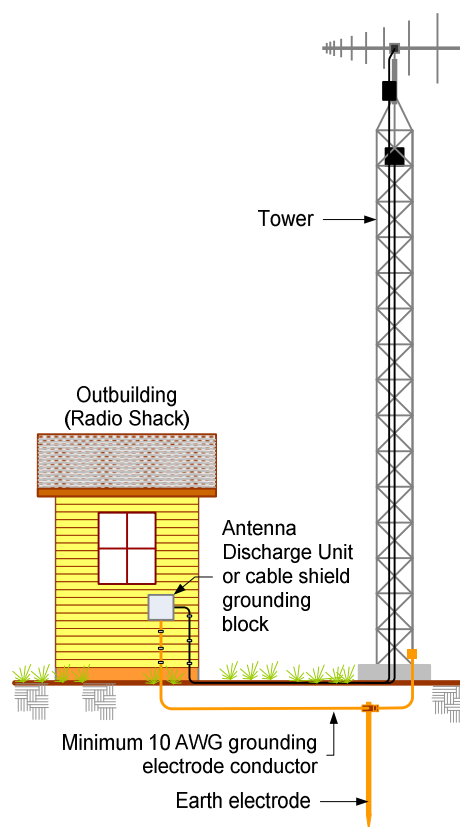


It should be noted that metal underground gas

pipings systems and aluminum never should be used as grounding electrodes, the former to eliminate the chance of explosion and the latter to eliminate high resistance joints due to aluminum corrosion.

Scenario 3: If an antenna is connected to equipment in an outbuilding or equipment enclosure that does not have ac power, then the building very probably does not have an intersystem bonding termination or a grounding electrode system. This setup usually involves an outbuilding (“radio shack”) for battery-powered equipment and is near a tower or mast. In that case, a grounding electrode must be installed for the antenna system and antenna discharge unit or cable shield grounding block (figure 14). The various earth grounding electrodes that may be used are the same as mentioned above [par. 250.52].

Fig. 14 – Scenario 3, no existing grounding system at an unpowered outbuilding or equipment enclosure. An earth grounding electrode is required for the antenna system



### Conductor size

The bonding conductor or grounding electrode conductor may be installed either inside or outside the building [par. 810.21(G)]. The conductors must not be smaller than 10 AWG copper, 8 AWG aluminum or 17 AWG copper-clad steel or bronze [par. 810.21(H)]. It is not necessary to use a separate bonding conductor or grounding electrode conductor for operational and protective purposes – one conductor can serve both purposes [par. 810.21(I)].

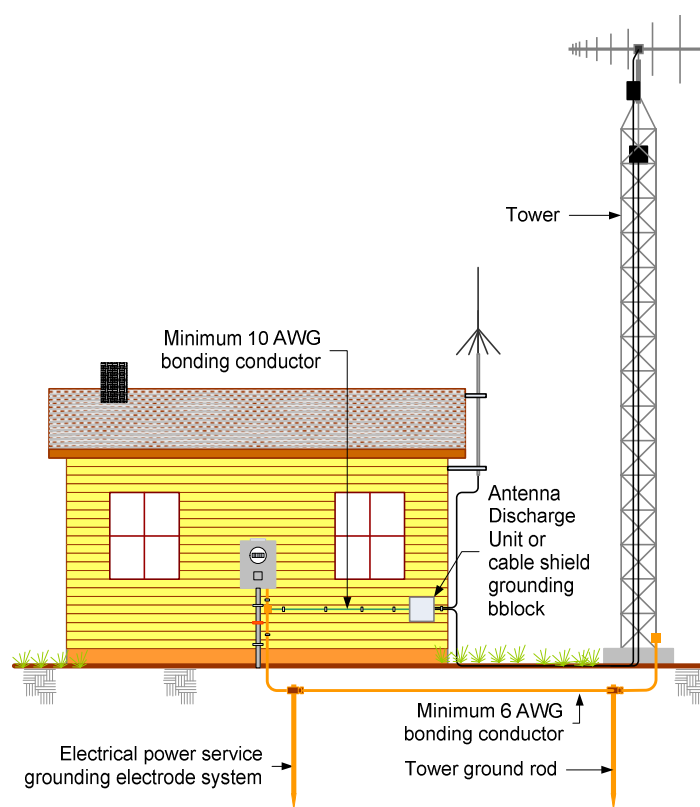
One or more ground rods usually are installed at the base of a tower or mast and at guy anchor locations (figure 15). These rods and other grounding electrodes must be bonded together as discussed above and then bonded to the building’s electrical power grounding electrode system with a minimum 6 AWG

conductor [par. 810.21(J)]. In some installations this bonding conductor may have to follow a somewhat long and circuitous route, perhaps on the other side of the building, but it is required nonetheless.

Conductors used for bonding and grounding should not be laid on the soil surface because they become a tripping hazard and are subject to damage by vehicles, lawnmowers or other yard equipment. Instead, make a slit in the lawn or dirt and push the wire down into it. It will become overgrown in a season or two. Sometimes a rock below the wire will push it up out of the ground by frost heaving in areas where the soil freezes in the winter, so be sure to examine the route and make repairs each spring.

Fig. 15 – Bonding an earth grounding electrode associated with a tower

When bonding the antenna system, it is important that the mechanical and electrical properties of the paths involved are determined by the connected members and not by the interconnection or bonding junction. This means that the junction must have negligible resistance and considerable mechanical strength and be made in such a way that it withstands all types of weather over long time periods.



### Grounding electrode connections

Bonding conductors and grounding electrode conductors associated with the antenna system must be properly connected to grounding electrodes. Suitable methods include exothermic welding (Cadweld and Thermoweld are familiar brands) and listed lugs, pressure connectors and clamps. National hardware and electrical supply stores normally sell only products that meet NEC requirements, so listed ground rod clamps are easy to obtain and are inexpensive (figure 16). Connections that rely only on solder are not acceptable [par. 250.70] because lightning-induced currents may melt the solder.

Fig. 16 – Ground rod clamps. The two clamps on the left are for copper-clad steel ground rods and can accommodate a single grounding electrode conductor. The clamp on the right is used for connection to galvanized pipe or conduit such as a mast or water pipe



The fittings must be compatible with the conductors and grounding electrode materials. Compatible materials usually are marked on the fitting. The two most common are Cu for copper and Al for aluminum. As you would expect, a fitting marked only Al cannot be used with copper wiring. Many fittings have dual markings (Cu/Al) and are suitable for both aluminum and copper wire. Once again, aluminum conductors should be avoided because it is difficult to make long-lasting connections to them.

It often is necessary to connect more than one conductor to a ground block or ground rod. Unless the connector or fitting is listed for multiple conductors, it may be used only with a single conductor; in other words, a separate clamp or other connection device may be needed for each conductor on a ground rod. Finally, fittings that are encased in concrete or buried in earth must be listed for direct burial. This will be marked on the fitting or its package.

## Costs

Proper bonding and grounding of antenna systems costs money. Coaxial cable shield ground kits cost US\$10 to \$35. Coaxial lightning arrestors cost US\$20 to several hundred dollars. Ground rods cost US\$20 to \$60 and the associated clamps cost US\$3 to \$10. Copper wire for bonding costs US\$0.30 per ft or US\$1 per meter, or more. Even on a simple installation, it is easy to spend a couple hundred dollars. However, those costs are low compared to the potential costs of doing nothing or doing it haphazardly.

## Conclusions

Electrical hazards due to lightning, powerlines and static buildup are associated with most antenna systems used in radio telescopes. The hazards are reduced by proper bonding and grounding and using shielded cables and surge protection. The application of these techniques involves common sense but it is easy to overlook the detailed requirements. In most of the United States, the National Electrical Code defines the detailed requirements for outdoor antenna system installations.

## References

- [1] NFPA 70, National Electrical Code, National Fire Protection Association, 2011
- [2] NFPA 780, Standard for the Installation of Lightning Protection Systems, National Fire Protection Association, 2004
- [3] Silver, H., Editor, ARRL Handbook for Radio Communications, ARRL, 2012

## Further reading on bonding, grounding and protection

- Block, Roger., The "Grounds" for Lightning and EMP Protection, Polyphaser Corp., 1987
- Block, Ron, Lightning Protection for the Amateur Station, Parts 1, 2 and 3, QST, 2002 (June, July and August) [ARRL members may download an archive copy: <http://www.arrl.org/arrl-periodicals-archive-search>]
- Frydeniund, M., Lightning Protection for People and Property, Van Nostrand Reinhold, 1993
- Hart, W. and Malone, E., Lightning and Lightning Protection, Interference Control Technologies, Inc., 1988
- Lightning Protection for Engineers, National Lightning Safety Institute (NLSI), 2004
- McCoy, L, How to Protect Your Station From Lightning, QST, 1962 (December) [ARRL members may download an archive copy: <http://www.arrl.org/arrl-periodicals-archive-search>]
- Military Handbook MIL-HDBK-419A, Vol. 1(Basic Theory) and 2 (Applications), Grounding, Bonding and Shielding for Electronic Equipments and Facilities, 1987 ( [www.tscm.com/MIL-HDBK-419A.PDF](http://www.tscm.com/MIL-HDBK-419A.PDF))
- Rakov, V. and Uman, M., Lightning: Physics and Effects, Cambridge University Press, 2006
- Rauber, R., Walsh, J., Charlevoix, D., Severe and Hazardous Weather, Kendall/Hunt Publishing Co., 2002
- Smith, A., Coupling of External Electromagnetic Fields to Transmission lines, 2<sup>nd</sup> Ed., Interference Control Technologies, Inc., 1989
- Sunde, E., Earth Conduction Effects in Transmission Systems, Dover Publications, 1968
- Vijayaraghavan, G., Brown, M., and Barnes, M., Practical Grounding, Bonding, Shielding and Surge Protection, Elsevier, 2004

## Appendix

As mentioned on page 5, the ARRL 2012 Handbook for Radio Communications [3] Chapter 28 (Safety) is incorrect in its discussions of some National Electrical Code requirements. Presumably this handbook edition is based on the 2011 NEC, and my comments below are based on the 2011 NEC. The following information, exactly as shown, was forwarded to ARRL on 14 December 2011. It remains to be seen if future handbooks are corrected:

Item 1 - Page 28.9 Antenna Conductors: One point of confusion in this chapter is that the line between good practice and NEC requirements often is blurred. For example, art. 810.52 requires the wire sizes cited in this section - this is made clear by the phrase "shall be" in the NEC - but the handbook says "should be".

Item 2 - Page 28.9 Lead-ins: The last sentence states that "...feed lines smaller than RG58 are likely not code compliant." NEC art. 810.3 requires that coaxial cables comply with art. 820. However, art. 820 has no requirements pertaining to coaxial cable sizes or RG-types.

Item 3 - Page 28.9 Antenna Discharge Units: The statement in this section "..., unless the antenna itself is permanently and effectively grounded, such as for a shunt-fed vertical" requires additional explanation. Antenna Discharge Units for receiving stations are covered by NEC art. 810.20, and this article does not allow exceptions for the antenna itself. On the other hand, Antenna Discharge Units for transmitting stations are covered in art. 810.57. This article allows an exception "Where the antenna is grounded with a conductor in accordance with 810.58,...." I believe the handbook needs to clarify this topic and provide more detail and to differentiate between antennas used only for receiving purposes and those used for transmitting. Not all users of the handbook are licensed radio amateurs with transmitters. There are many people who rely on the handbook for their receive-only stations.

Item 4 - Page 28.9 Antenna Discharge Units: The parenthetical statement "(The code exception for shielded lead-ins does not apply to coax, but to shields such as thin-wall conduit. Coaxial braid is neither "adequate" nor "effectively grounded" for lightning protection purposes)" is incorrect. There is nothing in Chapter 8 (or anywhere else in the NEC) that says the code exception does not apply to coaxial cable. As I mentioned in Item 2 above, art. 810.3 requires that coaxial cables comply with art. 820. Coaxial cable clearly is a "shielded lead-in" according to the NEC and, if properly grounded, can be used in place of an Antenna Discharge Unit. The NEC says nothing about thin-wall conduit. Also, putting terms in quotes such as "adequate" and "effectively grounded" is a dubious practice and does not help readers understand what is being said and why.

Item 5 - Page 28.9 Antenna Discharge Units: The last sentence in this section is incorrect at least in the context of the NEC - "An acceptable alternative to lightning arrestor installation is a switch (capable of withstanding many kilovolts) that connects the lead-in to ground when the transmitter is not in use." The NEC does not differentiate between a transmitter that is "in use" and "not in use". I believe this needs to be clarified. Also, how many is "many kilovolts"? This language is too loose and confusing to be of any use.

One last point: The NEC requires that Antenna Discharge Units be "listed". UL standard UL 452 covers antenna discharge units. However, at this time (December 2011) there are only three manufacturers that make listed products according to UL 452, and there are no devices that have specific radio amateur application. This certainly complicates compliance with the NEC, but it does not make the hazards any less important.

In short, the handbook sections on Lead-Ins and Antenna Discharge Units are of little use and are misleading as presently written. I hope they are improved in future editions. Errata may need to be issued on the present edition.

**Document information**

Author: Whitham D. Reeve

Copyright: © 2012 W. Reeve

Revision: 0.0 (Original draft started, 27 Sep 2011)  
0.1 (Added list of ARRL handbook problems, 2012)  
1.0 (Reformatted, 27 Dec 2018)

Word count: 5489

File size: 4951040