Title: ***Grounding and Bonding for the Radio Amateur: Good Practices for Electrical Safety, Lightning Protection, and RF Management***
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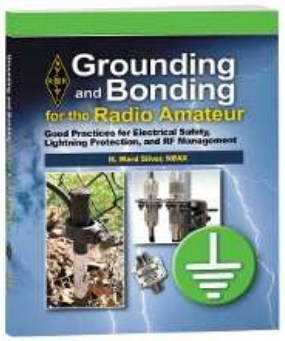

Grounding and bonding are very important aspects of any electronic installation including those in amateur radio astronomy observatories. It is not without controversy. One of the quickest ways I know to start a fist fight is to bring up the subject in a group of technical people, especially engineers. ***Grounding and Bonding for the Radio Amateur*** covers a subset of the overall subject. The book provides a good springboard for additional study and is cheap enough to not break the bank. The book targets radio amateurs in the USA but amateur radio astronomers face the same problems. Readers in other countries may find some useful concepts and ideas but they will use the book at their own peril because grounding and bonding to meet safety requirements differ around the world.

The author asks "*Why are grounding and bonding important?*" and then lists "*AC Safety*", "*Lightning Protection*", and "*RF Management*". A chapter is devoted to each. It is important that readers realize the subject of grounding and bonding includes more, such as personal and personnel safety (not just alternating current safety), audio and radio frequency noise control (not just radio frequency management) and fault current return path control (not just lightning protection). However, having a narrower scope keeps the book small and, perhaps, easier to follow.

Before briefly discussing each chapter, I will mention what I think are some deficiencies in ***Grounding and Bonding for the Radio Amateur***. First, it inadequately covers ***National Electrical Code*** requirements and appears to downplay that the NEC is adopted in almost every city, county and state in the USA. The NEC also is known as NPFA 70 [NEC] and as of this writing (fall 2018) the current edition is 2017. The NEC is updated and reissued every three years. The NEC has one purpose and that is the "*practical safeguarding of persons and property from hazards arising from the use of electricity*". It is not an engineering document and describes only the *minimum* requirements to achieve the stated safety goal. The NEC can be freely accessed online or printed versions can be purchased through any bookstore. The price of the NEC has risen over the years (like all books) and is now slightly more than 100 USD.

Government bodies – jurisdictions – in the USA adopt an electrical code and most often it is the NEC, but other electrical codes exist. The point is there is an electrical code in just about every jurisdiction. Not all jurisdictions immediately adopt the newest NEC edition and some adopt local modifications. Adherence to the electric al code is mandatory and not optional. These codes apply to radio amateurs and amateur radio astronomers and not just electricians or businesses (there are certain types of facilities exempted from the NEC including railway rolling stock, aircraft, ships, telecommunications and electric utility facilities, and so on). Ignorance is not bliss when it comes to the importance of electrical safety.

An example of how ***Grounding and Bonding for the Radio Amateur*** underplays the importance of the NEC is in a statement on page 3.13: "*Soldering to the* (ground) *rod is not recommended.*" In fact, the NEC specifically prohibits soldering as a means of connecting grounding system components including the ground rod (see §250.8(B) in the 2017 edition of the NEC). There is no "*not recommended*" about it. The reason is that heat generated in conductors by lighting or fault currents can easily melt solder and open the connection. In other places, the author uses the word "*should*" where, in fact, the NEC uses "*shall*". This simple word substitution can be very dangerous and has strong legal ramifications.

Second, the author too often calls out the use of "*heavy wire*" or "*suitably heavy conductor*". What does that mean? Books for the amateur radio market are most useful when they are prescriptive – when they describe specifically what to do and how to do it. This is especially important where safety is involved. Terms such as "*suitable*" and "*heavy*" are subjective and inadequately state what is required. How does one interpret "*Use materials that are adequately rated for lightning protection and have been shown to do the job!*"? A reader who bought ***Grounding and Bonding for the Radio Amateur*** to learn what is *adequate* or what *has been shown to do the job* will be disappointed. To be truly useful the information provided should be objective and include recommended values. Referencing credible documents or guides is better than nothing but that means the reader will have to search out and acquire yet more reading material. If it is important, it should be included in the book at hand.

Next, the book seems to have two different discussions about amateur radio tower bonding and grounding and their relationship to lightning protection. Lightning protection is a serious subject that should be discussed clearly and in the context of the NEC, which describes specific grounding and bonding requirements for radio system installations. The author does not mention the National Fire Protection Association (NFPA) lightning protection standard [NFPA780]; readers in regions with regular lightning should consider obtaining a copy. It currently costs about 65 USD and provides detailed requirements and drawings.

It is unfortunate that the book almost totally ignores photovoltaic systems (also called PV systems and solar panels). They are very common throughout the country, typically to offset or reduce electric utility charges and to power remote radio devices and other small point loads. NEC article 690 covers these systems including bonding, grounding and connecting to ac power systems. Because solar panels often are located on roofs and other exposed areas, they are easy targets for lightning. Although I have read many reports of radio frequency interference caused by PV systems, and many amateur radio astronomers avoid them for that reason, mitigation measures are possible in most cases. It clearly is important to discuss how to safely bond and ground these systems.

Finally, I felt the list of references in the *Resources for Information and Materials*, which is part of the *Appendix*, is quite limited but at least it does include two very good ones – [R56] and [HDBK419] – and both are free downloads and easily found by internet search. It is important to know that if these documents conflict with or are less stringent than local code requirements, the local code prevails.

The *Appendix* also includes tables of conductors but only American Wire Gauge (AWG) sizes. The conductor tables include conductor diameters and cross-sectional areas in non-metric units but curiously do not include conductor resistances, an important parameter in almost any conductor application. The *Appendix* also includes a table of sheet metal thicknesses, common electrical plug and receptacle drawings and pinouts and information

about ferrites used for noise reduction. A short glossary is provided at the very end of the book. The book has numerous line drawings, both schematics and block diagrams, and black-white images.

Now, I will discuss each of the six chapters in ***Grounding and Bonding for the Radio Amateur***, which are

1 – Introduction	2 – Grounding and Bonding Basics	3 – AC Power System Grounding and Bonding
4 – Lightning Protection	5 – RF Management	6 – Good Practice Guidelines

Chapter 1, Introduction, tries to answer the question "*Why is this book needed?*" The author explains that his own experiences while learning amateur radio along the way motivated him to write the book. He then goes on to very briefly discuss grounding and bonding, materials, tools and techniques. Except for tools, these topics are covered in more detail in subsequent chapters.

Chapter 2, Grounding and Bonding Basics, covers terminology and the consequences of current flow through the human body (often death, paralysis or chronic pain), but curiously leaves out the possibilities of fire and other damage caused by systems that do not have adequate means of voltage and current limitation. The author devotes a paragraph to the terms "*shall*", "*may*", and "*should*" and how they need to be interpreted. Oddly, he does not follow his own advice as I noted above. The author discusses the importance of standards and guidelines such as the ***National Electrical Code*** in this chapter but then says "*You will probably not need to do much more than check out or wire up some ac outlets, use a generator or solar panel, or run new power circuits to your station.*" This is a textbook example of understating the potential for self-caused dangerous problems. In my own professional experience investigating electrical problems of all types, I saw many examples of how people miss-wire "*some ac outlets*" or dangerously connect or "*use a generator or solar panel*" or incorrectly "*run a new power circuit*". These situations should be taken seriously, and the NEC has specific requirements for each of them. This is where a licensed electrician will increase your chances of not killing yourself or someone else or burning down your house or shack.

Things get even more interesting in Chapter 3, AC Power System Grounding and Bonding. This chapter discusses safety and shock hazards and ac power system grounding and bonding. Some of the information here is incomplete (for example, not all possibilities for correctly bonding a power panel are described) and I encourage readers to go beyond what is written there and make sure their work is safe and meets electrical code requirements. Hiring a licensed electrician to do the work is far better and safer than making a life-threatening mistake because of ignorance.

There appears to be two discussions in chapter 4, Lightning Protection, one on "*ham practice*" such as antenna radials used for RF performance and tower bonding and grounding and another on "*rules*" such as the NEC. Unfortunately, ***Grounding and Bonding for the Radio Amateur*** does not clearly state the difference between grounding and bonding for RF purposes and the minimum requirements specified by the NEC for safety reasons. For example, the NEC requires that a ground rod, if used to meet its requirements for a grounding electrode, must be at least 8 ft long and at least 5/8 in diameter. The author discusses the use of 4 ft ground rods but does not say these shorter rods only can be used to supplement the required electrodes. And, by the way, a 4 ft rod is not much of a ground electrode in any soil.

The author incorrectly states in chapter 4 "*There are two versions of the NEC: the code and the handbook*". On the contrary, the NEC itself is the only ***National Electrical Code***. The NEC Handbook is not a code book and must not be relied on as such; it merely is an NEC application guide and, in my opinion, not a very good one. I quit buying the handbook many years ago because I found it was not much more than a repetition of the NEC with added drawings, many of which did nothing to clarify the matter. It is possible the handbook has gotten better since I last looked at it, but I would not bank on it without closely examining a copy before purchase. The handbook is very expensive (about 200 USD) and twice the cost of the NEC itself.

There are other aspects of chapter 4 that can be confusing or, worse, can lead to incorrect and unsafe installations unless readers realize they will need to dig deeper to learn how to at least comply with electrical code requirements. I recommend readers approach this chapter with caution and, if nothing else, acquire the references already cited and make use of the free online access to the NEC. NEC Chapter 8, *Communications Systems*, Article 810, *Radio and Television Equipment* has specific requirements of interest to radio amateurs and amateur radio astronomers. Readers may find an article I wrote in 2012 useful, *Antenna System Bonding and Grounding Requirements in the USA* [Reeve12].

Chapter 5, RF Management, describes some of the perils, mostly noise and interference, involved in radio systems. However, missing from this chapter are actual examples of RF and audio noise mitigation and the actual results provided by the methods that are discussed. One practice recommended in this chapter will lead to disappointing results and frustration: The author recommends using THHN building wire for dc power cables and twisting the two conductors together. The letters THHN describe a type of wire insulation and jacket that is commonly available from electrical suppliers. Yes, the two power conductors should be twisted, which helps cancel common mode noise currents, but THHN building wire has a very slick nylon jacket that makes twisting and forming quite difficult. Readers are far better off using 300 V PVC insulated hookup wire, which is much easier to twist and form. Also, readers should use stranded rather than solid conductors for the same reason. Perhaps the biggest problem with this chapter is its heavy reliance on outside references. Again, I feel that if the information really is important it should be included in the book.

Chapter 6, Good Practice Guidelines, mixes code requirements with practices. Codes include regulatory requirements that are sometimes prescriptive and sometimes performance based. Of course, not everything that radio amateurs do is codified by government regulations (nor should they be), but their practices – the way they actually build things – must not conflict with legal and common-sense safety requirements. One thing that many technical people fail to realize is that there are often many ways to accomplish something – they erroneously believe that their way is the only way or that it is the only way because *so-and-so said so*. Practices will vary with the industry, region of the country or specific types of equipment or materials being used. When someone says "*this is the only way to do it*" they usually are wrong. Unfortunately, the author of ***Grounding and Bonding for the Radio Amateur*** recommends at least two online technical resources that suffer terribly from the "my way is the only way" syndrome.

Chapter 6 again mentions soldering ground connections (see above) and says "*Do not solder ground connections unless you are an expert at the use of high-temperature, sliver-bearing solder and gas torch equipment.*" As a reminder I will say again that the NEC prohibits soldering, including silver-soldering, in ground systems that are installed to meet its requirements. Exothermic welding is acceptable but that process is far different than

soldering. Missing from chapter 6 is a discussion on tools and shop practice – what tools you should have, how to choose the proper tools and how to use and take care of them.

In conclusion, readers need to be cautious when using ***Grounding and Bonding for the Radio Amateur*** and to verify the recommended methods before actually applying them. The book's value is in highlighting important subjects and concepts, but readers should go beyond what is written there.

Citations:

[HDBK419] Mil-Hdbk-419A, Grounding, Bonding, and Shielding for Electronic Equipments and Facilities, Vol. I and II, 1987

[R56] R56, Standards and Guidelines for Communications Sites, Motorola, 68P81089E50-B, 2005

[NEC] NPFA70, National Electrical Code, 2017: https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=70

[NFPA780] NFPA 780, Standard for the Installation of Lightning Protection Systems, National Fire Protection Association, 2017

[Reeve12] Reeve, W., Antenna System Bonding and Grounding Requirements in the USA, 2012, available at: http://www.reeve.com/Documents/Articles%20Papers/Reeve_AntennaSystemGroundingRequirements.pdf

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