ARRL Grounding and Bonding for the Radio Amateur by Ward Silver, N0AX

UK Safety Information

Introduction

George Bernard Shaw said that the British and the North Americans are two nations separated by a common language. This is evident from the differences in terminology used in describing earthing or grounding – depending on which side of the Atlantic you come from. In addition, from my experience of working in the United States (US), the US tends to develop its own standards without much attempt to harmonise with other countries' standards. They have enough problems getting the 50 states to agree! Additionally, the British power system and the US power system are different in domestic voltages, frequency and the general absence of an earth connection provided by the US utility. The GB1 utility usually supplies an earth connection – called a TN supply, where T or Terra – as in Terra Firma the Latin for dry land - stands for earth and N neutral. The latter results in British houses having ring mains incorporating circuit protective conductors connecting back to the properties earth terminal and consequently AC domestic apparatus are supplied with British three pin plugs and have the exposed metalwork already earthed (exposed-conductive parts in GB Wiring Regulations speak). US appliances need to have the earth connection and the appliance's wiring to earth supplied by the radio amateur and connected by the amateur, which leads to confusion when GB amateurs read US manuals.

During our years within Europe a lot of work has been undertaken through CENELEC and BSI to harmonise the standards for domestic equipment, particularly in the area of electromagnetic compatibly (EMC) in order that different items of domestic equipment can operate together without interference, plus the EU's low voltage directive, which concerns safety. This is an European led initiative, which has resulted in the CE markings on products for use in the EU. The US has its own system and equipment sold into the US market is required to comply with US standards, which have more of a focus on improving safety and reducing fire risk than EMC issues. This also results in clashes in standards such as appliance wiring colours. The US uses white for neutral and black for a single phase (called 'hot' in the US) terminal. For three phase the US uses red, black and blue colours, whereas for single phase installations we now use brown for phase (called 'hot' in US) and blue for neutral, in single phase installation. Hence, neutral can get also get 'hot' if an amateur confuses the US and GB colours. Three phase colours in GB cables are now brown, black and grey. This is in my view an area that indicates amateurs need to beware, if they have not received development inputs recently (from a reliable source).

This book is intended to guide amateurs operating in the US only and thus has a number of major and potentially dangerous pitfalls if it is inadvertently used by an amateur thinking it is also a British handbook. This is particularly so if the amateur is not aware of the latest requirements for Part P concerning building control, as ignorance is not an excuse in law and alterations to a property's earthing and/or installation without complying with building control can be a criminal offence. Readers should note that *ARRL Grounding and Bonding for the Radio Amateur* is intended as a model code of practice, for use when preparing initial installation designs in the US. However, even

Note 1 The term Britain or GB is used to denote England, Wales and Scotland. Northern Ireland is excluded from the discussion as they have different regulations as does the Rep of Ireland. They also do not use the NEC standard for their electrical installation code.

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in the US it requires discussion with the local State's building control authorities to obtain final design approval, before installation work can commenced. Following completion of the installation work, inspection and testing will be required where building control requires this.

Overview

For the Institution of Engineering and Technology (IET) Wiring Regulations terminology please see the RSGB EMC 07 leaflet for TT, TNS, TNC-S etc. In summary T= Earth, N=Neutral, S=Separate, C=Combined.

As stated above, the key requirement for any electrical installation work is to comply with the local building control regulations. In England and Wales these are known as the Building Regulations - Part P and include the need for notification of this proposed work to the local building control unit, before the work commences and testing/inspection where the person is not authorised to self-certify the work prior to completion and connection. Scotland has its own similar building regulations that shall be complied with. In most cases compliance with the IET Wiring Regulations will ensure compliance, but as usual the devil is in the detail and Approved Codes of Practice need to also be consulted along with a locally based Part P inspector, to ensure that the detail is agreed along with any local special requirements. Where lightning protection is required in GB, then additional measures are required that involve a specialist in the area approving the lightning protection measures and the Part P building control person approving the overall earthing system design and installation.

In Europe and Britain, the terminology surrounding the connection to the general mass of Earth differs from the terminology used in North America. For example, the ARRL book refers to 'grounding' but then says the British call this 'earthing'. In the IET Wiring Regulations 'earthing' is defined as 'Connection of the exposed-conductive-parts of an installation to the main earthing terminal of that installation'. The two words are not completely interchangeable in the way the author implies and in North America the concept of a 'main earthing terminal' where it does exist is different to ours. The term grounding in the US appears to cover both sides of the consumer's earthing installation – namely above ground and below ground connections, whereas our term is primarily above ground. This is possibly due to the US code being produced by the National Fire Protection Association, rather than the American IEEE, their equivalent to our IET2 (formerly IEE).

In addition, the way in which an electricity supply is provided by a power utility differs across North America, which in turn differs from the way the electricity supply is provided in Britain. Therefore, the diagrams showing North American consumer units are completely different to those you would see in most British domestic installation. For example, in the US you are told you shall bond the T and N connections together in the consumer unit, but in GB that would not apply in a TT or TNS situation and if the TNBC-S connection on a PME supply was done in the service cable cut-out you would not repeat it again in the consumer unit. The S part of TNC-S refers to the earth and neutral circuits being kept strictly separate once inside the consumer's premises. The T(earth) and N(neutral) are only combined (C) in the street and the service cable running to the property from the street. This utilises a TNC or protective neutral-earth (PEN) conductor. Once they are inside the property T and N are separate (S) hence the TNC-S and PEN conductors are definitely not permitted inside the property (which begs the question as to why they are permitted in the street!)

The IET Wiring Regulations is an international standard namely EN-BS 7671:2008 (revised 2015). It is non-statutory in that it does not have the force of law behind it in GB, but strict compliance with it does normally meet the various statutory requirements in Britain. The IET Wiring Regulations EN-BS 7671 are European harmonised standards (hence the EN) and are harmonised through the European CENELEC committee and IEC. It is understood that prior to Brexit other countries were looking to align their own electricity installation codes with EN-BS 7671.

Note 2 The IET is the UK's Institution of Engineering and Technology, formerly called the Institution of Electrical Engineers or IEE. Visit at http://www.theiet.org/

In the US the required standard is the National Electric Code (NEC) which has been adopted by the American National Standards Institute (ANSI) as a national code for initial design purposes only. This is because the NEC is regarded primarily as a 'model code' for States to adopt or change as required. Consequently, local building regulations in a US state can override the NEC, which means it is not universal across the whole of the USA. The ARRL book is based solely on the NEC requirements and warns you to check the State's building regulations.

In England and Wales the statutory building regulations require most electrical installation work to be notified to the Building Control Inspector and tested/inspected by a Part P authorised technical/electrician. Failure to do so can constitute a criminal offence. However, compliance with the IET Wiring Regulations is normally sufficient to comply subject to notification to building control and testing/certification by a Part P authorised person. In North America, the National Electricity Code does not guarantee compliance with building regulations.

ARRL Grounding and Bonding for the Radio Amateur is written on the lines of a model Code of Practice solely for the North American radio amateur, it is not suitable for use by the average British radio amateur in the context of the current GB building regulations. It could create problems for some British engineers, who remember the pre-1970s electricity networks but have not been retrained on the PME requirements and the latest IET Wiring Regulations and building regulations. Unfortunately, I often hear such people advising recently licenced amateurs to create separate star earth points and connect all apparatus in the station to that point, without determining if they have a TT supply – which they are unlikely to have!

Note that the term 'hot' in the ARRL book is misleading in that in GB the neutral is now regarded as a live or 'hot' conductor, due to the application of TNC-S or PME systems. I think this well illustrates the problem as with a hot neutral if you then follow the ARRL book and effectively connect this to earth through a massive earth mat at your home, you are going to risk attracting large load currents from your neighbours in the event of trouble with the mains cable's neutral-earth conductor. This is also called a protective earth-neutral conductor (PEN). I do recall when I worked for a GB utility being told of a row of cottages that had burnt down due to this problem when the PEN conductor was broken. Currently, there is on average at least one PEN conductor failure each day nationally, according to a reliable contact.

Comments on Chapters

Chapter 1 Introduction
The book is certainly needed if you intended to operate an amateur radio station in the United States or territories that adopt the US building regulations, such as parts of the Caribbean.

Figure 1.1 this is not generally applicable to GB as the means of 'grounding' does not comply with GB requirements. Also the terminology 'hot' or for that matter 'live' is not used in GB to mark conductors or terminals. In GB we do not normally undertake earth connection between equipment, in the way shown in this figure. It is normally undertaken through the individual three pin plugs and the house wiring and would not normally involve additional earth spikes as shown, except at the main earthing terminal (normally at the meter/service position).

Fig 1.2 shows the US requirement to install lightning surge protection on antenna cables prior to them entering a building. This is not as a rule required in GB by building regulations, although it is a good idea to consider it in say the Severn Valley, which has high lightning levels and on locally exposed high ground. In GB the lightning protection is required where the risk of a lightning strike risk exceeds 1 in 100,000. The earth ring shown around the antenna tower would broadly be similar to GB requirements, but would need checking with an approved electrican/technician.

You should note that the US distribution supply in the book is shown as coming off an overhead line with a house power pole transformer – this is not representative of a GB supply, which normally

uses underground cables and underground services in the urban areas and LV overhead lines with underground services in the rural areas and group HV/LV transformers not house pole units.

Chapter 2: Grounding and Bonding Basics

Fig 2.1 shows an arrangement for ground that would constitute a TT supply in GB. The majority of GB supplies are TN meaning TNC-S with some still TN-S supplies remaining until, the utility changes it to TNC-S. TT is now rare except in some pre-1970s properties in the rural community that have not been re-wired – or where GB amateurs have converted their property to TT for safety and to reduce mains conducted noise.

Fig 2.3 Shows a star ground connection. This would only be applicable in a TT installation and thus would not apply to the majority of GB properties with TN supplies. Even in a TT installation, it may be inappropriate as the domestic ring main would normally contain an earth conductor and any additional bonding would be undertaken at the main earthing terminal or as lightning protection at the tower.

Fig 2.4 shows the US single-point ground panel (SPGP). The SPGP arrangement looks to be a bespoke US arrangement. It could be used in a rural area where lighting surges are frequent but would not in my view be permitted to constitute the main earthing terminal, as it appears to do in this diagram. Any GB amateur proposing to use this due to say high lightning surge levels, would need to check with a specialist lightning contractor and their local building control first.

In GB the regulations concerning bonding have recently become more comprehensive for domestic property, particularly for TN supplies, than the applicable requirement in the US. Consequently, the ARRL book does not comply with GB requirements on bonding.

Chapter 3 AC Power System Grounding

Fig 3.3 shows a US power pole two phase supply, which is not applicable to GB, where a two phase and neutral supply is not usually provided to domestic premises.

Fig 3.4 gives US plugs and sockets which are not used in GB.

Fig 3.5 gives grounding and bonding which does not comply with GB electrical regulations. Fig 3.8 shows a US AC outlet which does not comply with GB electrical regulations

Fig 3.9 and 3.10 Are both US bespoke arrangements that do not comply with GB regulations for TN supplies.

Chapter 4 Lightning Protection

An interesting chapter and one that could do with translating into GB standards for actual installation work. This is an area where due to GB having a separate code for lightning protection this gets left out from many of our discussions or considerations. Having worked in central Africa and seen the effect of lightning strikes on antennas and power lines I have a healthy respect for this energy source and consider in GB we do not do enough as amateurs to protect our construction from this risk.

The chapter does give advice on clearances between a metallic tower and the shack/residence to reduce the risk of side flash or surge between the lighting hit tower and the domestic wiring. The ARRL author does make clear that commercial installations require a higher level of protection. As previously stated, before starting any installation work (following advice from an approved lightning electrician/technican), checks are needed on what is to be notified to building control and what they consider is required to achieve compliance, as locally they may have requirements for higher clearances, due perhaps to the severity of the storms experienced.

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Fig 4.4 would need additional measures taken if the property was TNC-S (i.e. PME) as the connection to neutral-earth at the property would be better than the utility system in the event of a broken mains neutral and the resulting load flows from adjacent properties could create a fire risk if the bonding cable were not sized to the same size as the properties service cable neutral, which could be 35 sq mm copper!! This means that Fig 4.5 is potentially dangerous for GB and is not applicable to a TN supply

Fig 4.8 shows a useful installation for an outside antenna where lightning is a likely. Provided the earth spike was clear of other house metal work it should be possible to install in GB but would need a lightning contractor and Part P electrician to confirm. It is advisable to also notify building control before starting any work.

Fig 4.9 AC in line power surge protector – if this is a part of the permanent installation then it needs to be notified to building control and tested/inspected prior to commissioning by a building control or Part P qualified electrician3.

Fig 4.13, 4.14 and 4.15, same comment as for Fig4.4

Fig 4.12 refers to the use of an arc gap on an insulated antenna. I will be enquiring with a UK antenna designer if he things this is a suitable means of reducing the occurrence of overvoltage following a lighting flash. The comments about lightning detectors are also useful, if you live in a lightning prone area such as Severn Valley. Arc gaps are used on outdoor power frequency equipment to reduce the occurrence of overvoltage due to lightning and power surges, where surge diverters are not considered necessary.

Chapter 5 RF Management
A good chapter except for Fig 5.1, 5.4, 5.5, 5.6, 5.7 which apply only to the US.

Chapter 6 Good Practice Guidelines
The article starts with a box stating that ‘Regardless of the advice in this or any other resources your local building codes and standards have priority…’. In other words, ‘buyer beware!’ Good chapter in principle, particularly concerning lightning protection, but the detail of connections is for NEC only, not BS EN 62305 plus IET Wiring Regulations with GB building Regulations. It is best regarded as a head-up as to what may be required for an antenna-tower in parts of GB, but as stated you need to check with a qualified lightning protection contractor and also a Part P contractor or your local building control person.

Fig 6.19 is in my view a good idea if you have a high power linear in the shack to keep the RF at bay. However, as we are not permitted to run the XXX kWs the US amateurs seem to run the issue probably does not come about for a properly connected 100 Watt station. Ladder feeds can create RFI so this may solve a problem in the shack where they are used. However, in GB the computer would still have its normal three pin plug with circuit protective conductor and any bonding would be additional and not in place of the normal earth connection through the three pin plug. However, if RFI persists then the solutions shown using additional RF bonding measures may solve the problem.

The check list on 6.34 is good as it lists key points to consider with the station. However, the solutions are now subject to building control in this country and not DIY situations unless you are fully up to date on the IET Regulations and Part P and are going to satisfy your local building inspector. If you do not get a pass slip (assuming you were permitted to proceed by the building inspector in the first placed) you will probably end up employing a Part P qualified electrician to fix what is non-complaint after your hard work!!

Note 3 An electrician may be fully qualified to do the work but may not be Part P authorised (for instance he/she may do mainly industrial installations), but could have Part P colleagues who can check and sign off on the installation without adding too much to the costs.

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A Personal Opinion

I enjoyed reading this book and found it very informative. There was a lot of déjà vu from things I have heard over the air from other GB operators who say ‘you should do ABCD’ or things I have read in US produced documents. Now I know where these come from. However, they are not GB compliant so be aware of this.

If I was going to the US or to any US territories such as the Caribbean to operate an amateur station, I would take a copy of this book with me to make sure I was making a safe and compliant installation. Clearly the NEC and IET Wiring Regulations are as different as night and day, but when in Rome you do as the Romans… and follow the NEC if that is the applicable model code, plus the local building codes.

The section on lightning protection is very useful although again it needs to be checked against the appropriate code, which is IEC 62305 which is issued by BSI as BS EN 62305: 2011. This contains certain approved British national amendments. It is advisable to obtain the advice of a lightning protection specialist if you believed that the tower/antenna system represents a significant risk of a lighting impulse/strike and resulting damage to life/property etc. The ARRL book raises the issue but does not provide a solution that would in my view meet the IET Wiring Regulations and BS EN 62305 – however it does give you a heads-up to having a potential problem. Again, I hear amateurs living on hill tops with high masts who do not appear to have any protection other than winding the mast down when they think a storm is on the way. Some more detailed risk assessment would though certainly be needed here to make any solution GB compliant. In fact it would need a separate addition for GB as it would not then apply to the US.

As George Bernard Shaw said, two nations divided by a common language.

John Woodhouse, G6GPF
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