

## EMC Advice Leaflet EMC 7

### Earthing and the Radio Amateur: Basic Leaflet

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#### Disclaimer

This leaflet is intended for members of the RSGB who have passed the Radio Amateur's Examination or who are studying for it. It assumes a knowledge of electrical principles and safety practice. RSGB Leaflets are made available on the understanding that any information is given in good faith and that the Society cannot be held responsible for any misuse or misunderstanding. Where any doubt exists a suitably qualified electrical contractor must be consulted.

The leaflet is only applicable to residential fixed electrical installations and does not apply to caravans, mobile homes or maritime installations. It also does not apply to the electrical systems of mobile or transportable units either, such as portacabins or vehicles used for event stations, emergency communications organisations such as Raynet or similar. The requirements for these are detailed in Part 717 of BS 7671.

#### Purpose of this leaflet

The leaflet discusses the background to the safety issues involved in connecting a Radio Frequency (RF) earth to an amateur radio installation and directs the reader to the appropriate sections of the current IET Wiring Regulations (BS7671) 18th Edition. <sup>1</sup>

There are a number of well-produced books available on electrical installation. A selection can be found in the IET Site Guide <sup>2</sup> and the Electrician's Guide to the Building Regulations. <sup>3</sup> These or similar books should be available through the public library service. The assumption is that where the requirements of the IET Regulations are complied with, then the installation will be satisfactory. However, where there is any question of the appropriateness or safety of any particular installation, a suitably qualified electrical contractor must be consulted.

The purpose of electrical protective earthing is to ensure that in the event of the failure or bypassing of electrical insulation, then the resulting phase to earth fault will divert the current flow to earth thereby allowing sufficient current to flow to either blow a fuse in the phase conductor or to operate the circuit protective device, thereby protecting persons in the vicinity from electrical shock. In particular, if a person is in physical contact with the metalwork of a faulty electric appliance and also in contact with the metalwork of a gas cooker then both the electrical appliance and the cooker need to be connected to the same protective earth to prevent hazardous voltage potentials occurring across the person's body.

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<sup>1</sup> See IET Wiring Regulations Institution of Engineering and Technology, BS 7671: 2018 + A2:2022

<sup>2</sup> IET On-Site Guide (BS7671:2011) incorporating Amendment 3: 2015 Institution of Engineering and Technology

<sup>3</sup> Electrician's Guide to the Building Regulations BS7671:2011 edition incorporating amendment 3: 2015. Institution of Engineering and Technology

## **Nomenclature**

In this leaflet the following terms are used:

- “Bonding Conductor” is the term for the wires used for the main protective bonding or supplementary bonding. Where necessary it includes the lightning protection system bonding conductor. Broadly speaking, bonding conductors are used to ensure that all metalwork in an installation is joined together.
- “Consumer Unit” is the enclosure which acts as the main distribution board from which the property’s wiring circuits originate.
- “Earth” (with a capital E) means the general mass of earth, which is taken to be at or near zero potential. When “earth” is used it means an earth at a given location. In some cases, there can be several earths and a voltage can exist between different earth conductors and the true Earth.
- “MET” refers to the property’s Main Earth Terminal. This is the connection bar within or close to the Consumer Unit to which the connection to Earth is made along with the Bonding Conductors.
- “Network” is used to denote the low voltage (LV) mains distribution network operated by the local distribution company from which the property receives its electricity supply.
- “Phase” This term is used with respect to a conductor connecting to one of the Network’s three phase conductors. This is also shown as “L”, “Live” or “Line” in wiring diagrams.
- “Property”. The term “property” is used to denote a permanent residential building such as a house, bungalow, flat or maisonette or in the plural a combination or a number of these.
- “Radio Frequency (RF) earth” means an earth that is part of an amateur radio installation.

## Domestic Installations

With very few exceptions, electricity installations in the UK will be one of three types.

These are called TN-S, TN-C-S and TT.

The letters stand for;

- T = Terre meaning earth (in French derived originally from the Latin for earth terra, as in “terra firma”)
- N = Neutral,
- C = Combined, and
- S = Separate.

The three configurations are shown in the figures below.

### TN-S Configuration

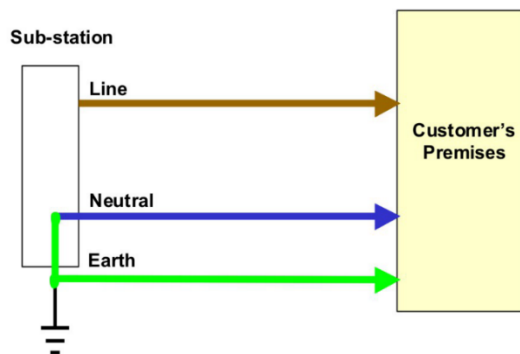


Figure 1. TN-S Configuration

Prior to the late 1970s many properties in the UK were wired to the TN-S system where the earth and neutral are electrically separated all the way back to the sub-station (as shown in Figure 1 above).

### TN-C-S Configuration

Since the late 1970s almost all properties have been supplied and wired to the TN-C-S system, shown below in Figure 2, using a Protective Multiple Earth “PME” system. In these installations the same conductor is used to carry earth and neutral from the sub-station to the property. Earth and neutral are then separated inside the premises, the two being bonded together near the Consumer Unit. In addition, an additional earth spike may be installed at the service position, for example if the house has a very long drive or is at the end of a cul-de-sac.

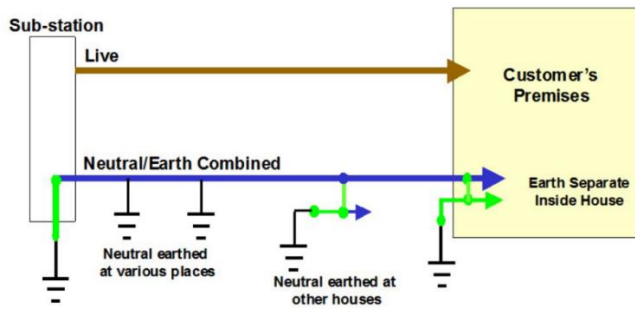


Figure 2. TN-C-S Configuration

### TT Configuration

The third system, most often found in older rural properties, is the TT system. This is shown in Figure 3. In this system there is a connection to Earth provided at the sub-station by the Network company and a local earth is provided at the customer's property.

Previously this represented the arrangement for overhead line supplies, as these did not have a separate earth conductor from the substation. Today this arrangement is still normally used where a TN-C-S customer's earth terminal cannot be provided, for example when the property incorporates a swimming pool or a caravan site.

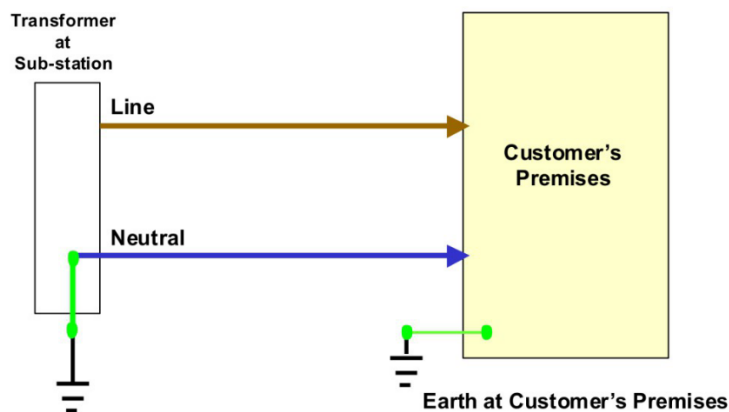


Figure 3. TT Configuration

### The Function of Earthing and Bonding in an Electrical Installation

The primary function of an earthing system is to provide thermal (i.e. fire) and touch voltage (i.e. electric shock) protection parts, such as those on an electrical cooker or other conducting surfaces such as copper central heating pipes. The earth impedance must be of a sufficiently low value to operate the appropriate fuse or circuit breaker within its required time limit (i.e. to reduce fire risk).

Earthing is a useful means of detecting faults and is used to assist in the protective measure of "automatic disconnection". Connecting the exposed metalwork of electrical equipment (known as exposed-conductive parts) to earth, gives rise to high currents flowing if the insulation of the equipment fails. This in turn causes fuses, circuit breakers, or residual current devices (RCDs) to

operate, thereby disconnecting the fault. Hence the disconnection happens automatically, without any user intervention.

Even with prompt disconnection, it is possible for a person touching the appliance to get an electric shock and this could be made worse if either:

1. The person is also in contact with other earthed metalwork at the same time, such as a radiator, kitchen sink or parts of an antenna installation; or
2. The earth fault loop impedance is too high, which would reduce the current flowing and slow the effective operation of fuses and circuit breakers.

The second point is readily resolved using modern RCDs that will provide rapid disconnection with high earth loop impedance's but is more problematic where older types of fuses are used.

Point 1 is a little more involved and BS 7671 requires that such metalwork is connected to the Main Earth Terminal (MET) of the installation to ensure that an equipotential zone is created. If all metalwork is at the same potential, then there is no likelihood of a potential difference occurring in the event of a fault with a piece of equipment, as it will all rise to the same fault voltage. If there is no potential difference, there is no risk of shock and that is the principle of protective bonding.

### **PME and the radio amateur**

Where TN-C-S is used in domestic supplies, the Network neutral is earthed at specified places along the circuit route from the sub-station as illustrated in Figure 2. This reduces the risk of the neutral conductor rising to a significant voltage above Earth under Network fault conditions - hence the use of the multiple earthing term.

The neutral is therefore earthed at a number of locations between the properties supplied and the sub-station and also at the end of the Network furthest from the substation.

In addition to avoiding the risk of shock from a fault, the PME customer's installation may need to be sized to cope with the fault Network load current, resulting from an open circuit Network neutral, passing through the bonding conductors. This is both a thermal and a fire risk issue. This is dealt with in more detail in the EMC7 Advanced Leaflet.

### **What is Bonding?**

As indicated in the previous paragraph, bonding involves connecting all metallic items that could import a different earth potential, such as metallic water pipes, gas pipes and central heating pipes to the Main Earthing Terminal. The MET is usually located adjacent to the Consumer Unit and/or the meter. However, if the incoming services are in plastic there is no requirement to Bond as they will not import an earth potential should an event occur which causes the Line conductor to come into contact with exposed conducting metal.

This is standard in all domestic installations, i.e. TN-C-S, TN-S and TT. However, in PME installations the regulations are more rigorous as the PME bonding may have to carry neutral load currents in the event of a broken Network neutral.

### **Special Requirements for PME Installations**

With PME installations there is special risk that in the event of a break or open circuit in the neutral on the utility's Network mains or service cable, the load side neutral with additional earthing attached to it from inside the property could provide a better return path to the substation earth, through say the tower or RF earth, than the Network now provides. This is shown in Figure 4.

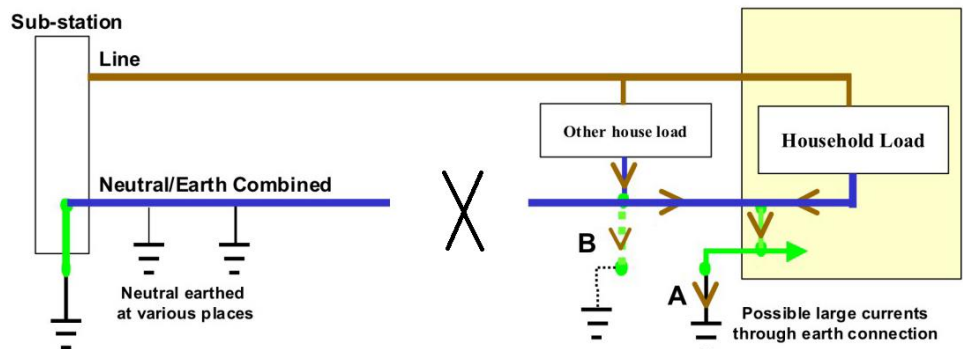


Figure 4. Ruptured neutral in a TN-C-S Configuration

In addition, under Network phase to earth fault conditions, the voltage of the neutral can rise to abnormal levels as it is now carrying heavy fault current back to the substation. This means that all properties with the TN-C-S or PME connection will experience these abnormal neutral voltages on their earth systems inside the property. Therefore, greater attention must be paid to equipotential bonding in PME installations.

Figure 4 illustrates how the household load current completes the circuit by passing through the earth connection at A, which could be a tower earth. Some current from neighbouring houses could also flow by this route depending on the earth conditions in those houses, as at B in Figure 4. The current flowing through the earth impedance will cause the protective earth and all the metalwork connected to it in the house to rise above the true Earth potential of the general mass of earth. In extreme cases this could approach the mains supply voltage. Additionally, it is possible for large currents to flow through the bonding conductors giving rise to a potential fire risk. The magnitude of the current would depend on where the neutral break is, and the earthing conditions in the customer's premises and in neighbouring houses. Although such situations are rare, when they do occur, they can cause severe damage to radio equipment and/or the property.

**Using electrical equipment in the garden from a PME System**

Equipment specifically intended for outdoor use such as hedge clippers and lawn mowers are double insulated, having no earth connection. However, it is advisable to use an RCD protected socket to feed these. This also applies to any amateur radio equipment used outside on a temporary basis, which has a mains voltage feed. The reason for not exporting the PME house earth into the garden is that the appliance earth can be at a different potential to the general mass of Earth, which the garden will represent.

**Antenna Installations**

Antennas can have a connection to earth through the transceiver or any linear amplifier and hence to the Main Earthing Terminal, so there is a small chance of a voltage existing between the antenna and the general mass of Earth. This is comparable to the outside tap situation, and while the risk of even a small shock is minimal, it is good practice to ensure that exposed conductive parts of the antenna are out of reach or are suitably insulated. However, where an antenna is connected to earth this will require thought as to the impact of the earth connection being brought back into the shack through the antenna cable. Radio antenna towers require more complex earthing and this is covered in detail in the EMC7 Advanced Leaflet.

## Finding Out About Your Installation

### ***Important notice***

***When undertaking Network repairs and modifications, most Distribution Network Operators (DNOs) now bond the neutral and earth together even on old cables.***

***Therefore it is advised to always treat domestic supplies as TN-C-S (i.e. PME) unless it can be definitively proved otherwise.***

If your property was built after 1980 then it will most likely have either a PME installation or a TT installation.

When a visual inspection of the meter board is undertaken and a PME label is observed, this confirms it is a PME installation. Where it is TT, this will be again found by inspection, as no earth terminal will be provided at the metering point from the Network company's cable or overhead line neutral.

Properties built prior to 1980 may have been converted to PME or had PME originally installed as part of a PME pilot scheme during the late 1970s.

TN-S properties, which still have separate neutral and earth service connections, still represent a significant number of properties, but it is best to have an installation check undertaken by a qualified electrical contractor to confirm this if you are uncertain. The rule with a property that does not have a TT installation and may be TN-S, is to assume it is PME until you are certain it is not. This means that cross-bonding of any amateur station equipment is required where the equipment has an AC mains connection.

By having an Electrical Inspection Condition Report carried out, this has the advantage that your earth resistance and earth loop impedance will be checked, along with the condition of the installation.

### **Part P Requirements in England & Wales**

All but the most basic of electrical work (such as changing a light fitting or replacing a damaged socket) is now notifiable in England and Wales under Part P of the Building Regulations. This means that either the homeowner should notify Building Control about the intended work and have this inspected and certified on completion, or the homeowner can go to a Part P registered electrician to undertake the work and notify Building Control accordingly.

It should be noted that Part P of the Building Regulations requires that earth electrodes installed as part of the electrical installation shall be notified to the buildings inspector and that if they are not installed by a person with the required authorisation to sign off on the installation, they will need to be inspected and tested by someone who is Part P Registered.

Similar arrangements exist in Scotland and Northern Ireland.

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*RSGB EMC Committee*

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