CHAPTER 5

INTERNAL GROUNDING (EARTHING)

This chapter provides requirements for grounding (earthing) communications site equipment within a facility. The following topics are included:

NOTE: Throughout this chapter the terms *grounding* and *earthing* are used synonymously.

5.1 INTRODUCTION

Proper bonding and grounding (earthing) of equipment is essential for personnel safety and system reliability. Because of the increase in circuit density and the advent of lower-voltage integrated circuit devices, communications systems equipment is now more vulnerable than ever to damage resulting from lightning activity and power line anomalies. Inadequate or improper equipment bonding and grounding can permit a difference of ground potential to exist between system components, which may result in injury to personnel, system failure, and equipment damage.

The requirements and guidelines in this chapter are derived from a compilation of local and national codes, widely accepted industry codes and standards, and good engineering practices. Such codes and standards are from, but not limited to, the following standards organizations:

- American National Standards Institute (ANSI)
- Institute of Electrical and Electronics Engineers (IEEE)
- National Fire Protection Association (NFPA)
- Telecommunications Industry Association (TIA)
- Underwriters Laboratories (UL)
- United States Department of Defense (DoD)
- United States Federal Aviation Administration (FAA)
- United States National Weather Service

References to the specific industry codes and standards on which this chapter is based are provided throughout. The requirements and guidelines in this chapter are provided to enhance personnel safety and equipment reliability.

Safety of personnel and protection of sensitive electronics equipment from ground faults, lightning, ground potential rise, electrical surges, and power quality anomalies is of utmost importance at any communications site. Though unexpected electrical events like lightning strikes and power surges cannot be prevented, this chapter provides design and installation information on communications site grounding (earthing) systems that may help minimize damage caused by these events.

WARNING

Grounding and bonding alone are not enough to adequately protect a communications site. Transient voltage surge suppression (TVSS) techniques, using appropriate surge protection devices (SPD), shall be incorporated at a communications site in order to provide an adequate level of protection. See Chapter 7 for details and requirements.

WARNING

The AC power system ground shall be sized appropriately for the electrical service and shall be approved by the authority having jurisdiction.

An internal grounding system **shall** have low electrical impedance, with conductors large enough to withstand high fault currents. The lower the grounding system impedance, the more effectively the grounding electrode system can dissipate high-energy impulses into the earth.

All site development and equipment installation work **shall** comply with all applicable codes in use by the authority having jurisdiction. Grounding systems **shall** be installed in a neat and workmanlike manner (NFPA 70-2005, Article 110.12 and NFPA 780-2004, section 1.4). Where conflicting, the more stringent standard should be followed. Government and local codes **shall** take precedence over the requirements of this manual.

Unusual site conditions may require additional effort to achieve an effectively bonded and grounded (earthed) site. See Chapter 2, "Site Design and Development". In these instances, consultation with Motorola Engineering or with an engineering firm specializing in grounding system design is recommended.

Some of the benefits of a properly designed and installed low-impedance grounding system are described below. See ANSI T1.333-2001, section 4; ANSI T1.334-2002, section 5.1; IEEE STD 142-1991, section 1.3; IEEE STD 1100-1999, section 3.3.1; and NFPA 70-2005, Article 250.4 for additional information.

- To help limit potential differences between conductive surfaces caused by electrical disturbances such as electrical power faults, lightning strikes and electrostatic discharges.
- To help provide fault current paths of sufficient current carrying capacity and low impedance to allow overcurrent protection devices to operate.
- To help limit the voltage caused by accidental contact of the site AC supply conductors with conductors of higher voltage.
- To help dissipate electrical surges and faults, to minimize the chances of injury from grounding system potential differences.
- To help dissipate the voltages caused by lightning.
- To help maintain a low potential difference among exposed metallic objects.

- To contribute to reliable equipment operation.
- To provide a common signal reference ground.

5.2 COMMON GROUNDING (EARTHING)

At a communications site, there **shall** be only one grounding (earthing) electrode system. For example, the AC power system ground, communications tower ground, lightning protection system ground, telephone system ground, exposed structural building steel, underground metallic piping, and any other existing grounding system **shall** be bonded together to form a single grounding electrode system. Underground metallic piping systems typically include water service, well castings located within 7.6 m (25 ft.) of the structure, gas piping, underground conduits, and underground liquefied petroleum gas piping systems. (ANSI T1.313-2003; ANSI T1.333-2001; ANSI T1.334-2002; IEC 61024-1-2, section 2.4.4; IEEE STD 1100-1999; NFPA 70-2005, Articles 250.58, 250.104, 250.106, 800.100, 810.21, and 820.100; and NFPA 780-2004, Section 4.14).

Interconnection to a gas line **shall** be made on the customer's side of the meter (NFPA 780-2004, Section 4.14.1.3). See Chapter 6, "Power Sources" for additional information on grounding and bonding requirements of power sources.

The objective of grounding and bonding system components to a single point is to minimize any difference of potential that may develop between individual components within the system and within the equipment site or area. To reach this objective a low-impedance internal single-point ground system is required for all communication equipment, support equipment, power systems, and other items and materials located within the building, shelter, room or area of the same building.

A **single point ground system** is defined as a single point, typically a master ground bus bar (MGB), within a shelter, equipment building or room, where all communications equipment, ancillary support equipment, antenna transmission lines, surge protection devices (SPDs), and utility grounds are bonded. The single point ground system must be effectively connected to a grounding electrode system as described in this chapter and in Chapter 4, "External Grounding (Earthing)".

The **system** is defined as all equipment required for proper communications system functionality at the site, and includes but is not limited to:

- Communications and support equipment
- Power systems
- Power distribution systems
- Voice, data and video circuits
- Antenna systems
- Global Positioning System (GPS)
- Surge protection devices
- Support components and material.

The **equipment site** or **area** is defined as the equipment building, shelter, room or area within another room where communications equipment or systems may be located and includes but is not limited to:

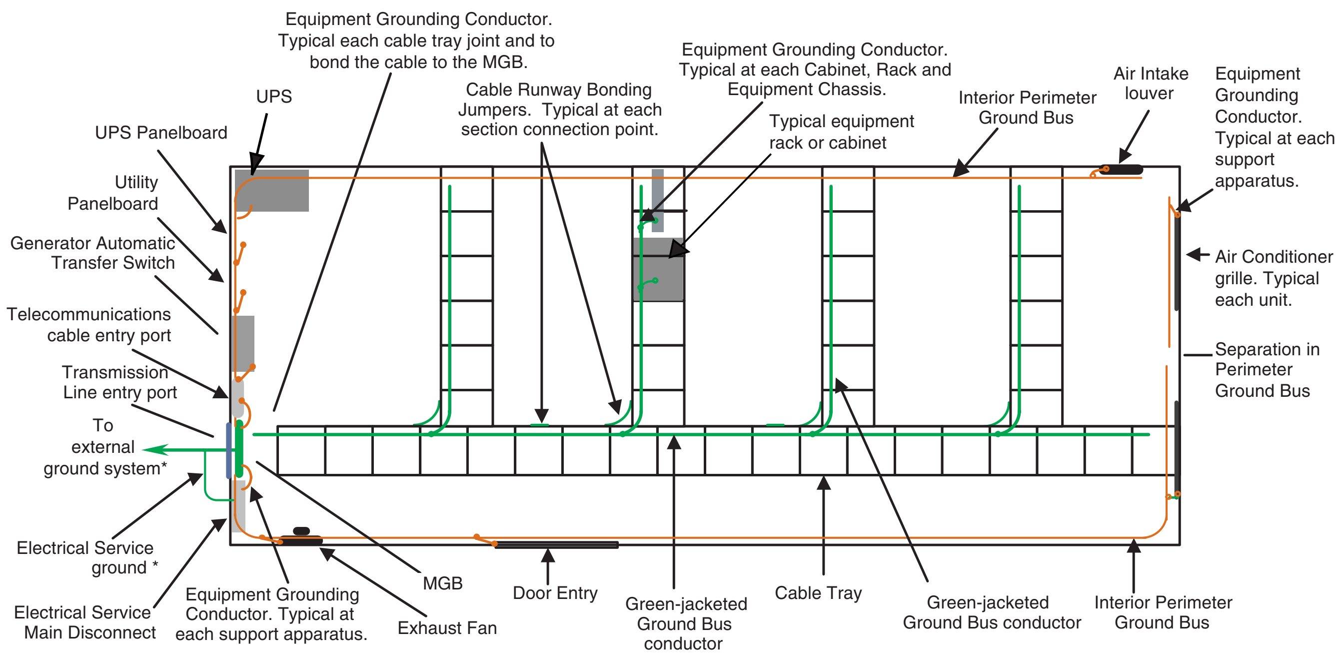
- Heating, ventilation and air conditioning (HVAC) systems
- Fire suppression systems
- Power distribution systems
- The building structure

5.3 GROUNDING (EARTHING) SYSTEM COMPONENTS AND INSTALLATION REQUIREMENTS

This chapter provides guidelines and requirements for establishing an internal grounding (earthing) system within a standalone equipment shelter, single-story building and multi-story building. The guidelines described in this chapter **shall** also be utilized for establishing an internal grounding system within an outdoor equipment vault, enclosure, or cabinet.

All new site design, development and construction should have a prime objective of establishing a single point internal ground system for all interconnected communication systems and networking systems located within the facility. To help achieve this objective, all utilities and telecommunication cables should be coordinated to enter the facility through a common wall, room, or area within the facility. The preferred configuration for a stand-alone equipment shelter is to have all utilities enter the structure through a common wall as close as practical to the transmission line entry port location. The main electrical service disconnect must be located on the shelter wall at the service entrance. For additional details on main service disconnect, see "Circuit Protection" on page 6-8.

If it is unavoidable that utilities enter an existing or new stand-alone equipment shelter at different locations, additional grounding is required to adequately dissipate high amounts of electrical energy from a lightning strike or possible power fault. The single point grounding location for this type of structure must be located next to the electrical service entrance location and as close as practical to the transmission line entry port location. See Figure 5-1 for a high level overview of the preferred internal grounding system design.



* NOTE: No exterior ground system conductors shown. Electrical service grounding electrode conductor must be bonded to external site ground system.

FIGURE 5-1 STAND-ALONE SHELTER WITH COMMON ENTRY LOCATION

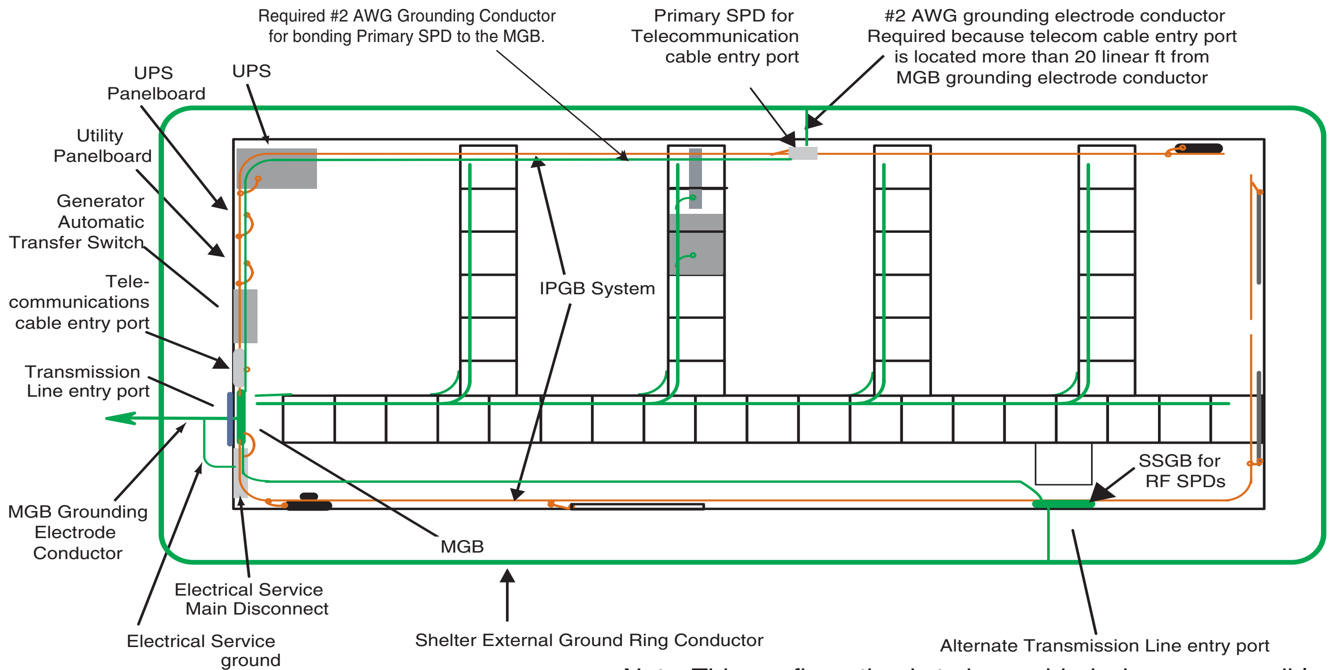


FIGURE 5-2 STAND-ALONE SHELTER WITH DIFFERENT ENTRY LOCATIONS

The preferred configuration for a single-story building is to have all utilities enter the structure through a common wall, room or adjacent rooms as close as practical to each other. The single point grounding location for this type of structure must be located at the utilities entrance location, preferably close to the building's electrical service (power) ground. See Figure 5-3 for an overview of the preferred internal grounding system design.

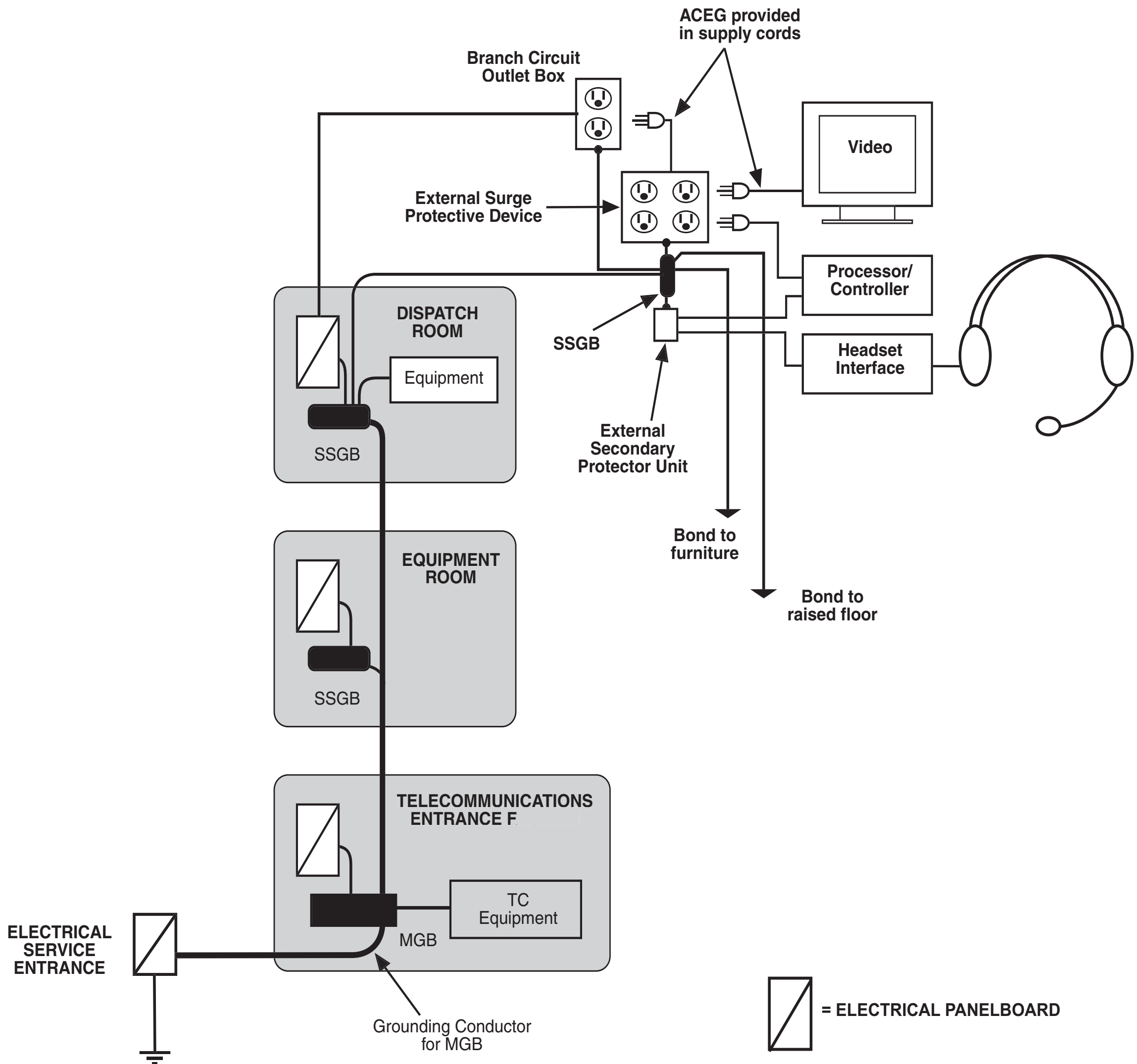


FIGURE 5-3 SINGLE-STORY BUILDING WITH COMMON ENTRY LOCATION

The preferred configuration for a multi-story building is to have all utilities enter the structure through a common wall, room or adjacent rooms as close as practical to each other. The single point grounding location for this type of structure must be located at the utilities entrance location preferably close to the building's electrical service (power) ground. See Figure 5-4 for an overview of the preferred internal grounding system design.

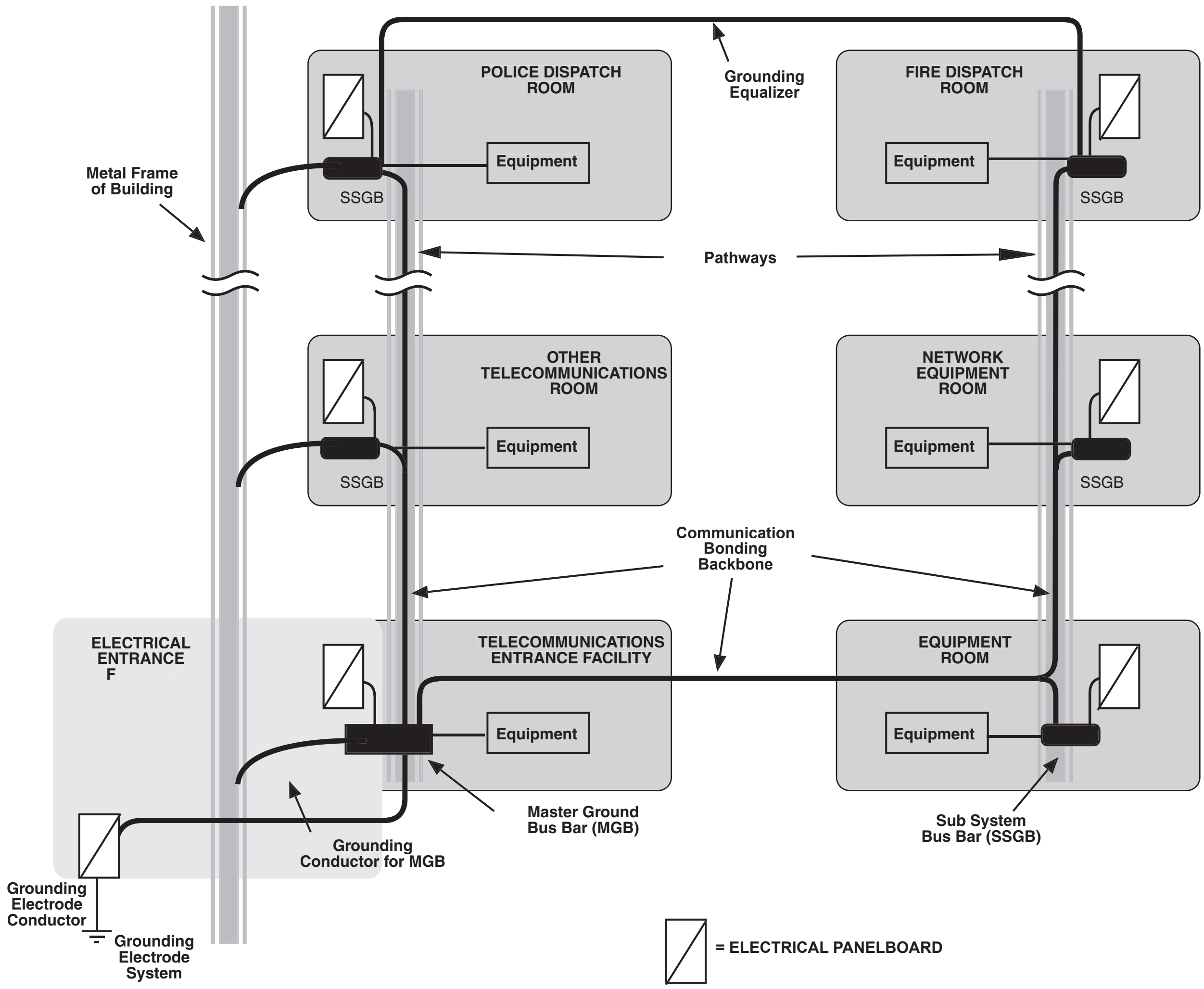


FIGURE 5-4 MULTI-STORY BUILDING WITH COMMON ENTRY LOCATION

An effective low-impedance internal grounding system can be achieved through the use of the components listed below, all of which must be effectively bonded together so that there is minimal difference in potential among them. Figure 5-5 shows the major components of a typical internal grounding system.

- Master Ground Bus Bar (MGB)
- Sub System Ground Bus Bar (SSGB)
- Rack Ground Bus Bar (RGB)
- Grounding conductors

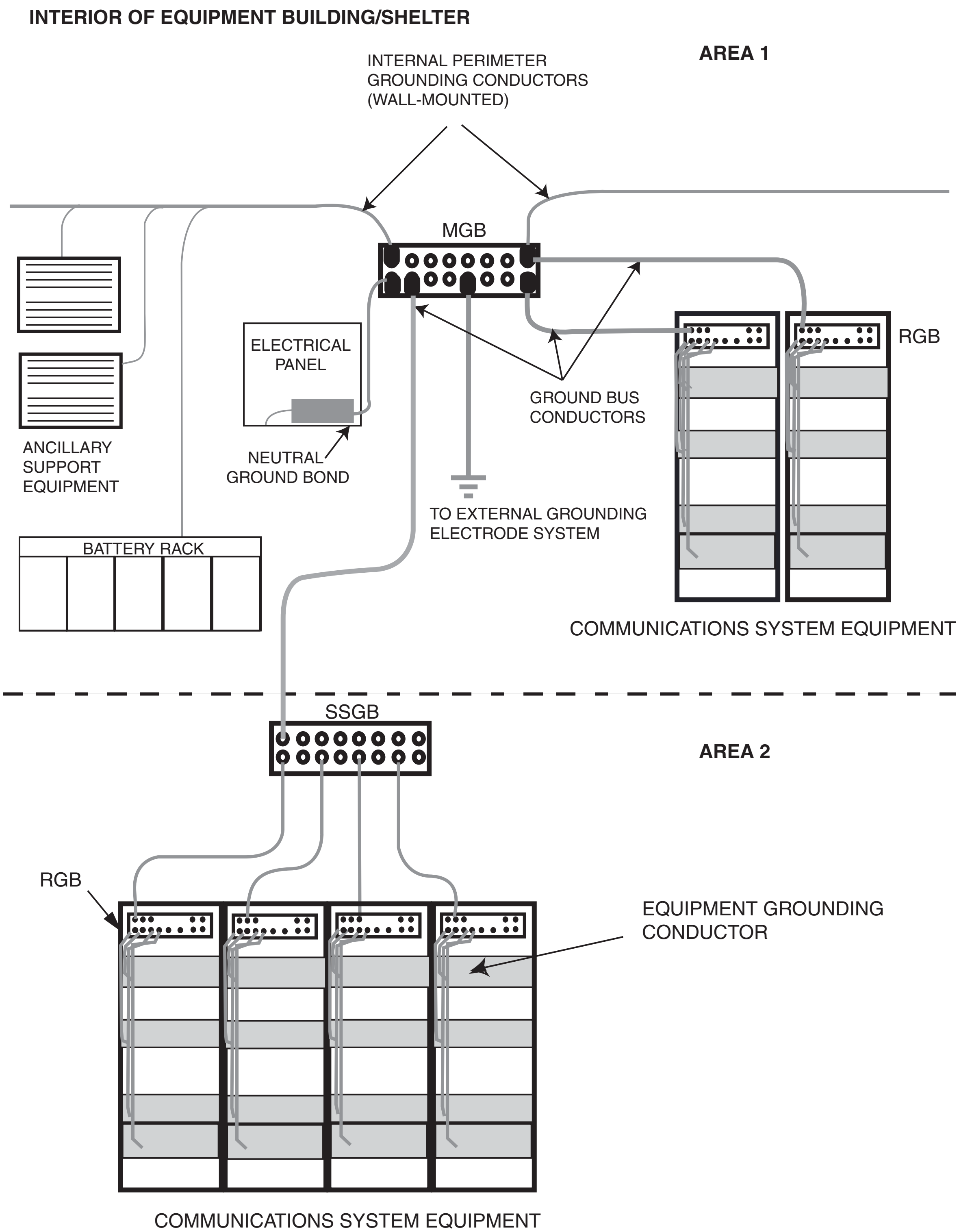


FIGURE 5-5 TYPICAL SINGLE-POINT INTERNAL GROUNDING SYSTEM

5.3.1 MASTER GROUND (EARTH) BUS BAR

The purpose of the master ground bus bar (MGB) is to provided a convenient internal grounding (earthing) termination point for the communication system and to serve as a dedicated extension of the site's common grounding electrode system. The MGB functions as the primary internal earth reference point for all equipment ground bus conductors, grounding conductors and communications equipment within the facility. Typically, there should only be a single MGB per building (ANSI-J-STD-607-A-2002 and ANSI T1.334-2002).

NOTE: Large buildings or campuses with multiple power feeds may require special design considerations that are beyond the scope of this document. Consultation with Motorola Engineering or with an engineering firm specializing in grounding system design is recommended in these instances.

A single MGB **shall** be installed for the communications system within a shelter, building, room or equipment area. The MGB should be located in close proximity to the electrical service entrance and installed with insulated mounting hardware. It may also be installed in an assembly of communications equipment cabinets as deemed necessary to ensure an effective bonding point for all equipment earthing conductors. A typical MGB with insulated mounting hardware is shown in Figure 5-6.

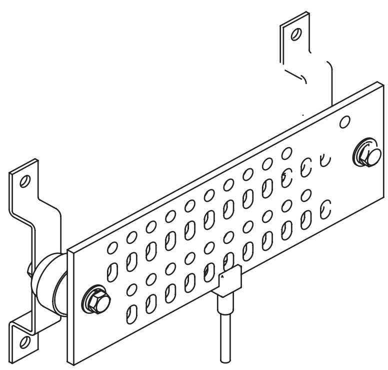


FIGURE 5-6 TYPICAL MASTER GROUND BUS BAR

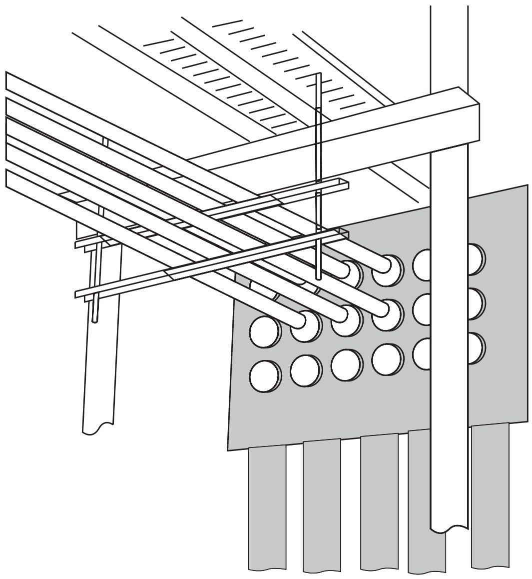
5.3.1.1 MGB SPECIFICATIONS

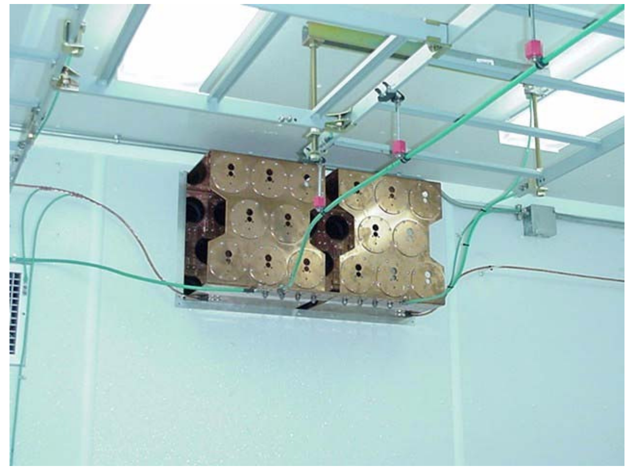
The MGB **shall** be a copper bus bar with predrilled holes that provide for the use of standard-sized lugs. It is recommended that the bus bar be electrotin plated for reduced contact resistance. The MGB **shall** be sized in accordance with the immediate application and consideration should be given to future growth of the site. The MGB **shall** be listed by a nationally recognized testing laboratory (ANSI-J-STD-607-A-2002). See Table 5-1 on page 5-10 for additional specifications and requirements.

TABLE 5-1 MGB SPECIFICATIONS

Item	Specification
Material	Bare, solid Alloy 110 (99.9%) copper bus bar or plate of one piece construction. May be electrotin-plated.
Minimum Dimensions NFPA 70-2005, Article 250.64)	Height: 50.8 mm (2 in.) Thickness: 6.35 mm (0.25 in.) Length: Variable to meet the application requirements and allow for future growth. 305 mm (12 in.) is recommended as the minimum length.
Mounting brackets	Must be suitable for the application.
Insulators	Polyester Fiberglass 15 kV minimum dielectric strength Flame resistant per UL 94 VO classification
Conductor mounting hole: Number and Dimensions	Dependent on number of conductors to be attached Holes should be 11 mm (0.4375 in.) minimum on 19 mm (0.75 in.) centers to permit the convenient use of two-hole lugs
Method of attachment of grounding electrode conductor.	Exothermic welding Irreversible crimp connection Other suitable irreversible crimp connection process

NOTE: A single properly installed integrated cable entry port of solid copper construction, electrically continuous between the interior and exterior of the structure through which it is mounted and with adequate surface area for proper termination of the internal grounding conductors, may be used as the MGB and external ground bus bar **only** if the site is properly designed for such a configuration. See "Grounding (Earthing) Electrode System Component and Installation Requirements" on page 4-7 for additional information on the external ground bus bar (EGB). Figure 5-7 shows an integrated cable entry port.





NOTE: Coaxial ground kits are located within the integrated panel and are not shown.

FIGURE 5-7 INTEGRATED CABLE ENTRY PORT BULKHEAD (OUTSIDE AND INSIDE VIEWS)

5.3.1.2 MGB LOCATION

Whenever practical, the MGB should be located within 610 mm (24 in.) of the transmission line entry into the building, equipment shelter, room, vault, enclosure or cabinet, preferably on the same wall or at the same entry location as the electrical service and the telecommunications cables. This configuration allows for a single point ground window to be established for the internal grounding (earthing) system. Figure 5-8 shows an example of this configuration for a stand-alone equipment shelter.

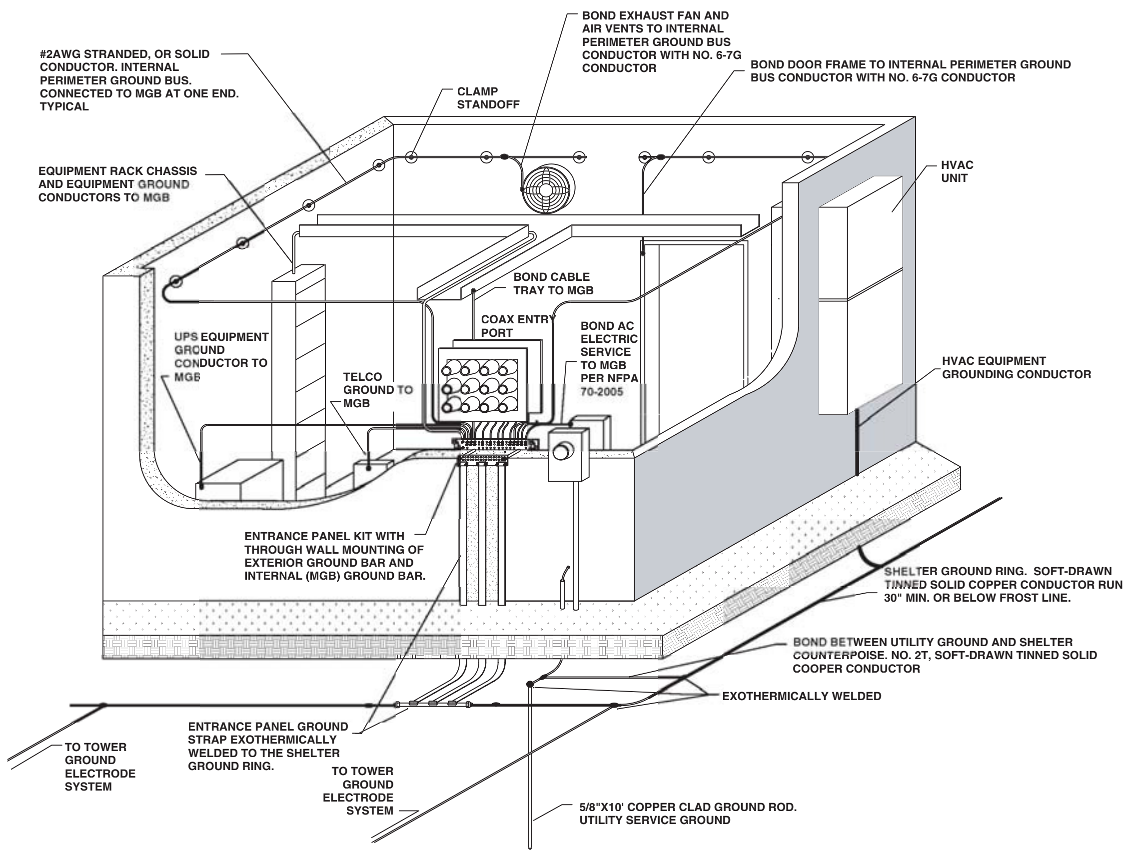


FIGURE 5-8 STAND-ALONE SHELTER WITH COMMON ENTRY LOCATION

The MGB must be insulated from its support structure just below the point where the transmission lines enter the facility, shelter or enclosure. In facilities or shelters where the transmission lines enter through a wall at floor level or through conduits within the floor or ceiling, the MGB should be located on the wall or floor immediately adjacent to the transmission lines entry point. In all cases, the MGB must located in a position that provides the shortest and straightest routing of the grounding conductors to the grounding electrode system.

In facilities where the transmission lines, the electrical service and the telecommunication cables enter at different locations, the MGB must be located as described within this chapter. In all cases the transmission lines, the telecommunication cables and the electrical service **shall** be effectively bonded back to the MGB, and the MGB **shall** be effectively bonded back to the grounding electrode system as described within this chapter.

5.3.1.3 BONDING: MGB-TO-GROUNDING (EARTHING) ELECTRODE SYSTEM

The installation specifications of the MGB and the acceptable methods for bonding the MGB to the site's grounding (earthing) electrode system are listed below. The following requirements are from ANSI-J-STD-607-A-2002 and other standards as noted.

- The MGB **shall** be insulated from its support structure. A minimum 51 mm (2 in.) separation from the supporting surface is recommended to allow access to the rear of the bus bar.

- The MGB grounding conductor **shall** extend from the MGB to the grounding electrode system with the shortest and straightest routing possible (ANSI T1.334-2002).
- When the communications system is located in a large or multi-story building, the MGB grounding conductor **shall** extend from the MGB to the service equipment (power) ground with the shortest and straightest routing possible.
- The MGB grounding conductor **shall** be of a copper material and may be insulated. If the conductor is insulated, the jacket **shall** be listed for the application as described within this chapter (ANSI T1.334-2002).
- When bonding back to an external grounding electrode system, it is strongly recommended that the MGB grounding conductor be multi-stranded, bare, individually tinned, copper.
- The MGB grounding conductor **shall** be 35 mm^2 csa (#2 AWG) minimum, and **shall not** be smaller than the largest ground bus conductor or equipment grounding electrode conductor installed within the internal grounding system (ANSI T1.334-2002, and NFPA 70-2005, Article 250.64(F)).
- The MGB grounding conductor **shall** be secured to the MGB by exothermic welding, listed compression two-hole lug, or irreversible compression-type connection device (ANSI T1.334-2002).
- The MGB grounding conductor **shall** be bonded to the external grounding electrode system with an exothermic weld or a listed irreversible compression device (ANSI T1.334-2002).
- Where exposed to physical damage, the MGB grounding conductor **shall** be protected and the conductor or its enclosure **shall** be securely fastened to the surface on which it is carried (NFPA 70-2005, Article 250.64(B)).
- The MGB grounding conductor should be free of any splices. Should a splice in the grounding electrode conductor become necessary, splicing **shall** be permitted only by listed irreversible compression-type connectors or by the exothermic welding process (NFPA 70-2005, Article 250.64(C)).
- The MGB grounding conductor **shall** be run to the grounding electrode system in a direct manner with no sharp bends or narrow loops. The grounding conductor bend angles (included angle) **shall not** be less than 90 degrees nor have a bending radius of less than 203 mm (8 in.) (ANSI T1.313-2003). When routing the MGB grounding conductor through a perimeter wall to the external grounding electrode system, the grounding conductor should be routed through the wall in a PVC or flexible non-metallic conduit sleeve at a 45 degree angle towards the grounding electrode system. See Figure 5-9 for an example of MGB grounding electrode conductor routing.

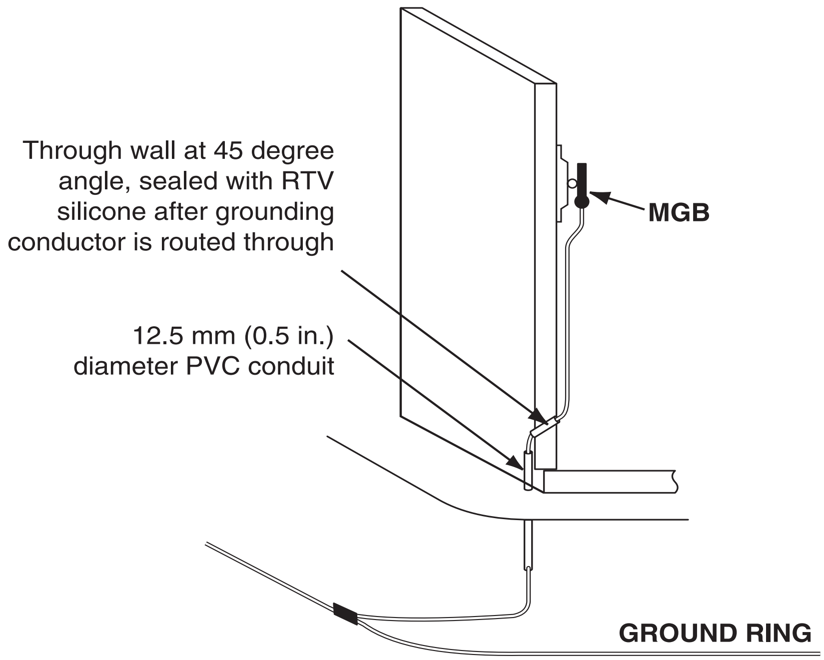


FIGURE 5-9 ROUTING OF MGB GROUNDING ELECTRODE CONDUCTOR

- The MGB grounding conductor should not be placed in ferrous metallic conduit. If local building codes require metallic conduit or sleeves, the grounding conductor **shall** be bonded to each end of the conduit using a listed grounding bushing or a bonding jumper of the same size, or coarser than, the required enclosed grounding electrode conductor (ANSI T1.334-2002, ANSI T1.313-2003 and NFPA 70-2005, Article 250.64(E)).
- Unless both ends of the grounding conductor are clearly visible, the conductor must be clearly labeled on both ends (ANSI T1.333-2001). In large and multi-story commercial buildings, each communication grounding and bonding conductor should be labeled as close as practicable to its point of termination in a readable location. The label **shall** be nonmetallic and should include the following information shown below (ANSI-J-STD-607-A-2002).

IF THIS CONNECTOR OR CABLE IS LOOSE OR MUST BE REMOVED, PLEASE CALL THE BUILDING TELECOMMUNICATIONS MANAGER

5.3.1.4 ACCEPTABLE GROUNDING (EARTHING) OF THE MGB

The following are considered acceptable for use as a grounding (earthing) electrode system at a communications system facility:

- In stand-alone building or equipment shelter, the MGB **shall** be bonded back to the common external grounding electrode system ground ring conductor (ANSI T1.334-2002 and ANSI T1.313-2003). See Chapter 4, “External Grounding (Earthing),” for external grounding electrode system requirements.

- In a small, large or multi-story building, the MGB grounding conductor **shall** extend from the MGB to the service equipment (power) grounding electrode system (ANSI-J-STD-607-A-2002).
- Where any of the following exist at a building or structure, they **shall** be effectively bonded together to form a common grounding electrode system and the MGB may bond to any point on this grounding electrode system: a metallic underground water pipe, the metal frame of the building or structure, concrete-encased electrodes, a ground ring conductor encircling the building or structure, rod or pipe electrodes and plate electrodes. (See NFPA 70-2005, Article 250.50 and 250.52 for additional information.) See Chapter 4, "External Grounding (Earthing)," for external grounding electrode system bonding requirements.

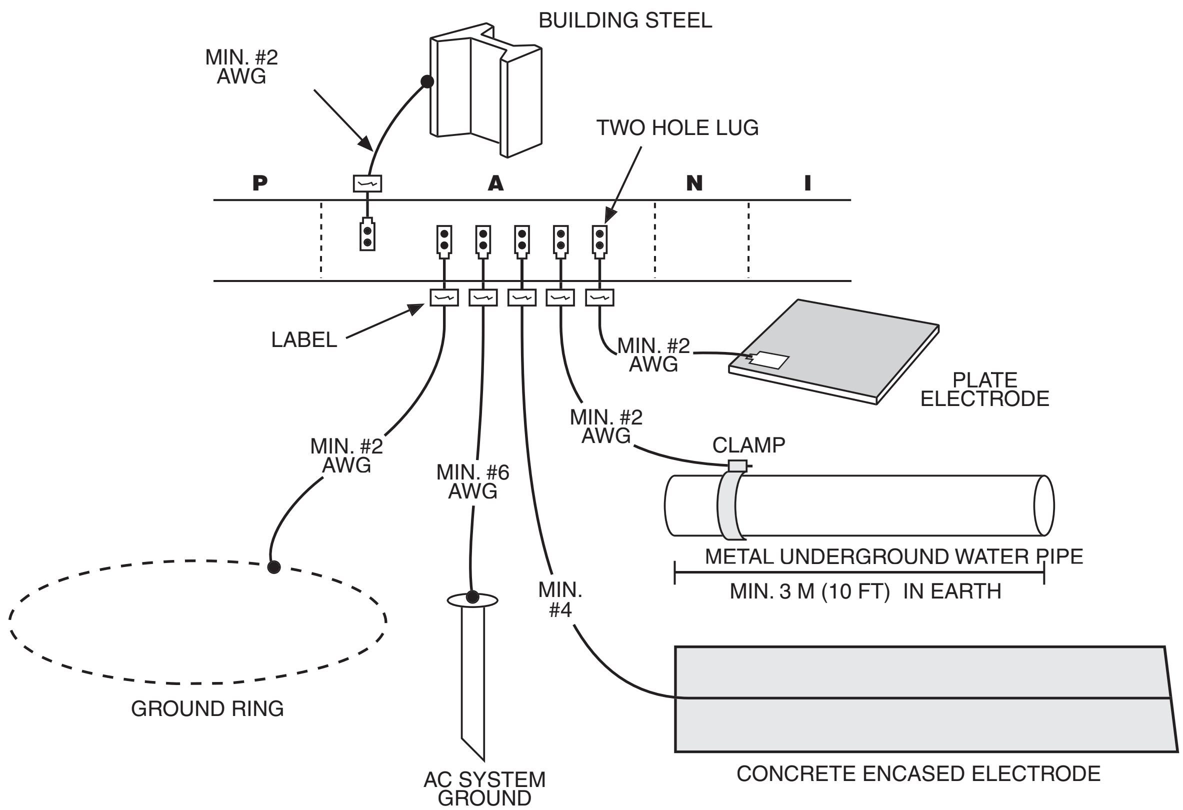


FIGURE 5-10 TYPES OF ACCEPTABLE GROUNDING ELECTRODE SYSTEMS

5.3.2 SUB SYSTEM GROUND (EARTH) BUS BAR

A Sub System Ground Bus Bar (SSGB) may be installed within a generator or power distribution room, a communications subsystem equipment room or area separate from, but associated with, the main communications equipment room or area and located within the same building as the MGB. In some applications the SSGB may be referred to as a telecommunications ground bus bar (TCGB), an isolated zone ground bus bar (IZGB), an ancillary ground bus bar (AGB), a logic ground bus bar (LGB), a frame ground bus bar (FGB), a telephone cable ground bus bar (TCGB), or an equipment reference ground bus bar (ERGB).

The SSGB provides a single termination point for all internal ground bus conductors, internal perimeter ground bus conductors, or equipment grounding conductors within a communications subsystem equipment room or area as defined herein. By having all equipment and ancillary support apparatus within the communications system equipment area bonded to a SSGB, differences in potential between communications system components are minimized and the probability of personal injury, system failure, or equipment damage greatly reduced.

A SSGB **shall not** be used when the associated equipment is located in a separate shelter or building, even if the shelter or buildings are adjacent to one another. A shelter added as a permanent attachment to an original building or shelter, which receives AC power from the same electrical service as the original building or shelter, is not considered a separate shelter or building for the purpose of this paragraph. See Figure 5-11 for an example of some acceptable SSGB configurations.

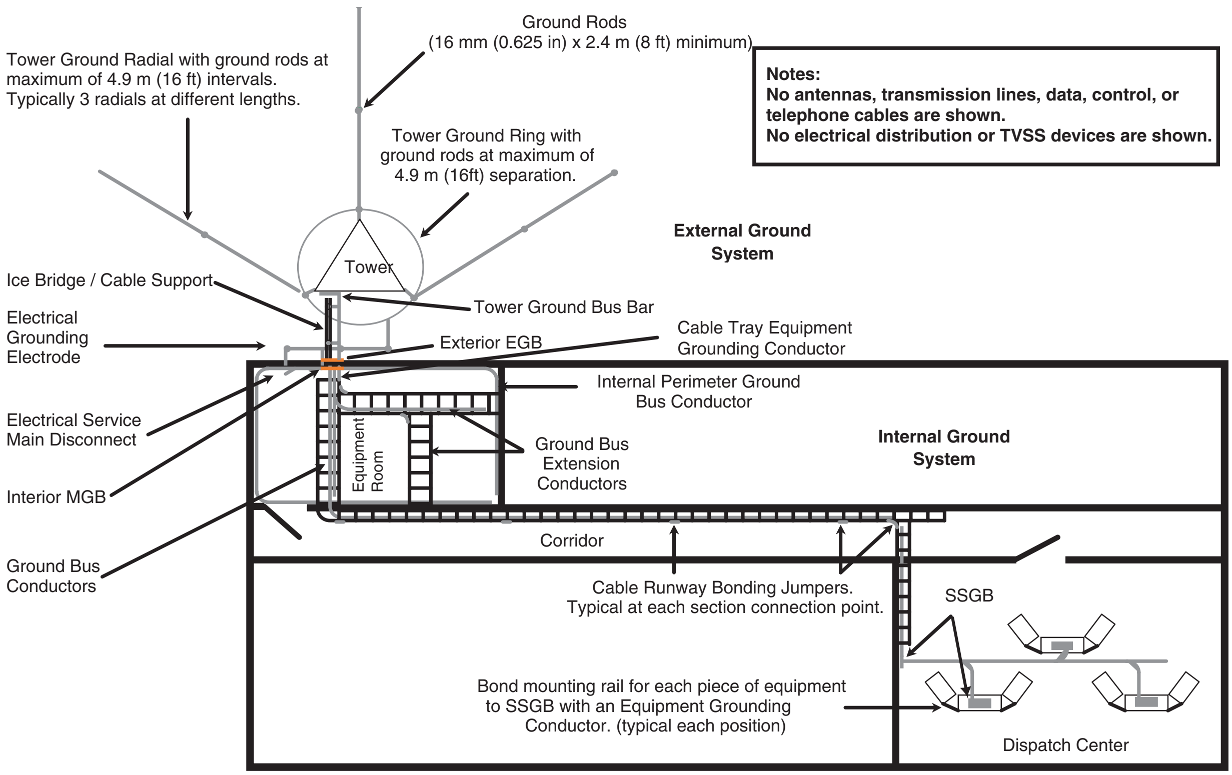


FIGURE 5-11 EXAMPLE OF SSGB CONFIGURATION

A SSGB may be installed in an assembly of communications equipment cabinets or at a network operator position as necessary to provide an effective bonding point for all equipment grounding conductors. Installation of a single rack, cabinet or chassis within a room or area does not require the installation of a SSGB as defined in this section, though one may be installed if desired.

5.3.2.1 SSGB SPECIFICATIONS

The SSGB **shall** be a copper bus bar with predrilled holes that provide for the use of standard sized lugs. It is recommended that the bus bar be electrotin plated for reduced contact resistance. The SSGB **shall** be sized in accordance with the immediate application and consideration should be given to future growth of the site. The SSGB **shall** be listed by a nationally recognized testing laboratory when it is placed within a building facility (ANSI-J-STD-607-A-2002) and it should be listed when placed within other type equipment locations. See Figure 5-12 for a typical layout of conductor mounting holes and see Table 5-2 for additional specifications and requirements.

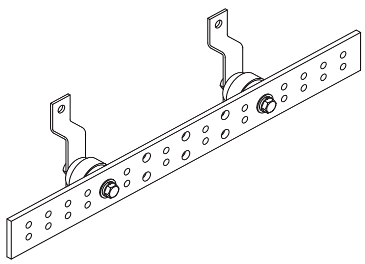


FIGURE 5-12 EXAMPLE OF SSGB

TABLE 5-2 SSGB Specifications

Item	Specification
Material	Bare, solid Alloy 110 (99.9%) copper bus bar or plate of one piece construction. May be electrotin-plated.
Minimum Dimensions (ANSI-STD-J-607-A-2002)	Height: 50.8 mm (2 in.) Thickness: 6.35 mm (0.25 in.) Length: Variable to meet the application requirements and allow for future growth. 305 mm (12 in) is recommended as the minimum length.
Mounting brackets	Must be suitable for the application.
Insulators	Polyester Fiberglass 15 kV minimum dielectric strength Flame resistant per UL 94 VO classification
Conductor mounting holes	Dependent on number of conductors to be attached. Holes should be 11 mm (0.4375 in.) minimum on 19 mm (0.75 in.) centers to permit the convenient use of two-hole lugs.
Method of attachment of grounding conductor.	Exothermic welding Irreversible crimp connection Other suitable irreversible crimped 2-hole lug

5.3.2.2 LOCATION

When used, the SSGB **shall** be located within the communications equipment room or area at the point where it is most convenient to terminate all ground (earth) bus conductors.

Although not recommended, and not a good design practice, occasionally exterior transmission lines and other telecommunication cables must enter an area served with a SSGB (i.e., not served by the MGB). In these instances special design criteria must be considered to ensure that potential differences between the location of the SSGB and the MGB are minimized. For these applications, additional surge suppression devices may be required on any interconnecting power, data, audio, telephone or telephone type circuits, even though they are routed within the same building. If the SSGB serving a transmission line or other communication cable entry point is located more than 6.1 linear metres (20 linear feet) from the MGB's grounding electrode system (the point where the MGB grounding electrode conductor enters the earth), the SSGB **shall** have a properly sized grounding electrode conductor installed directly to the site's common grounding electrode system with the shortest and straightest routing possible (NFPA 70-2005, Articles 800.100, 810.21, 820.100 and 830.100). Consultation with Motorola Engineering or other engineering firm is suggested in these instances.

For communication sites installed in large or multi-story commercial buildings, a SSGB **shall** be located inside each communications equipment room. A SSGB **shall** be installed as close to the panelboard as is practicable, with adequate clearance around it to comply with applicable local electrical codes. Where a panelboard for the communications equipment is not installed within the room, the SSGB should be located near the communication bonding backbone conductor at a location that allows the shortest routing of the grounding conductors. Multiple SSGBs may also be installed within the same room to aid in minimizing bonding conductor length and terminating space. Multiple SSGBs within a room **shall** be bonded together with a conductor of the same size as the communication bonding backbone conductor, with splice bars, or as described within this chapter. (See ANSI-J-STD-607-A-2002 for additional information.) See Figure 5-41 on page 5-67.

5.3.2.3 BONDING THE SSGB TO THE GROUNDING (EARTHING) SYSTEM

The installation specifications for the SSGB and the acceptable methods for bonding the SSGB back to the site's grounding system are listed below. The following requirements come from ANSI-J-STD-607-A-2002 and other standards as noted.

- The SSGB **shall** be insulated from its support structure. A minimum 51 mm (2 in.) separation from the supporting surface is recommended to allow access to the rear of the bus bar.
- The SSGB grounding conductor **shall** be of a copper material and may be insulated. If the conductor is insulated, the jacket **shall** be listed for the application as described within this chapter (ANSI T1.334-2002).
- The SSGB grounding conductor **shall** be 35 mm^2 csa (#2 AWG) or coarser, and **shall not** be smaller than the largest ground bus conductor or equipment grounding conductor bonded to it (ANSI T1.334-2002 and NFPA 70-2005, Article 250.64(F)).
- The SSGB grounding conductor **shall** be secured to the SSGB by exothermic welding, listed compression two-hole lug, or irreversible compression-type connection device (ANSI T1.334-2002).
- The SSGB grounding conductor should be free of any splices. Should a splice in the grounding conductor become necessary, splicing is be permitted only by listed irreversible compression-type connectors or by exothermic welding (NFPA 70-2005, Article 250.64(C)).

- The SSGB grounding conductor **shall** be bonded to the MGB, a collocated SSGB, or to a communication bonding backbone conductor as described within this chapter.
- When its required that the SSGB be bonded back to the external grounding electrode system, it is strongly recommended that the SSGB grounding electrode conductor be multi-stranded, bare, individually tinned, copper.
- The SSGB grounding electrode conductor **shall** be bonded back to the external grounding electrode system with an exothermic weld or a listed irreversible compression device (ANSI T1.334-2002).
- SSGB grounding electrode conductors located in areas with the potential for physical damage **shall** be protected and the conductor or its enclosure **shall** be securely fastened to the surface on which it is carried (NFPA 70-2005, Article 250.64(B)).
- The SSGB grounding electrode conductor **shall** be run to the grounding electrode system in a direct manner with no sharp bends or narrow loops. The grounding conductor bend angles (included angle) **shall not** be less than 90 degrees nor have a bending radius of less than 203 mm (8 in.) (ANSI T1.313-2003). See Figure 5-13.

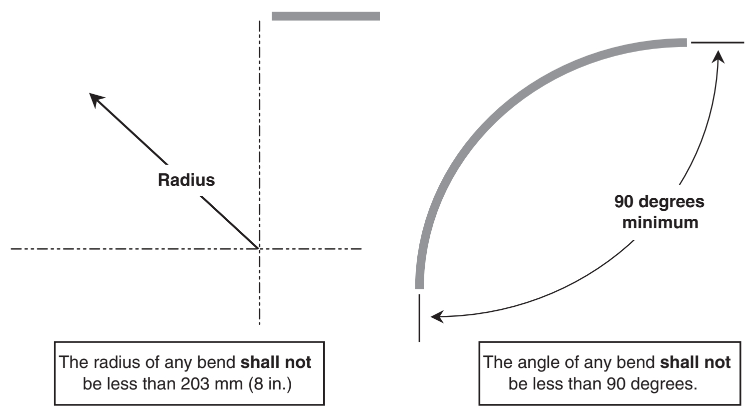


FIGURE 5-13 ACCEPTABLE GROUND CONDUCTOR BENDING

- When routing the SSGB grounding conductor through a perimeter wall to the external grounding electrode system, the grounding conductor should be routed through the wall in a PVC or flexible non-metallic conduit sleeve at a 45 degree angle towards the grounding electrode system.
- The SSGB grounding conductor should not be placed in ferrous metallic conduit. If local building codes require metallic conduit or sleeves, the grounding electrode conductor **shall** be bonded to each end of the conduit using a listed grounding bushing or a bonding jumper of the same size, or coarser than, the required enclosed grounding electrode conductor (ANSI-J-STD-607-A-2002, ANSI T1.334-2002, ANSI T1.313-2003 and NFPA 70-2005, Article 250.64(E)).
- Unless both ends of the grounding conductor are clearly visible, the conductor **shall** be clearly labeled on both ends (ANSI T1.333-2001). In large and multi-story commercial buildings, each communication grounding and bonding conductor should be labeled as close as practicable to its point of termination in a readable location. The label **shall** be nonmetallic and should include the information shown below (ANSI-J-STD-607-A-2002).

IF THIS CONNECTOR OR CABLE IS LOOSE OR MUST BE REMOVED, PLEASE CALL THE BUILDING TELECOMMUNICATIONS MANAGER

5.3.3 RACK GROUND (EARTH) BUS BAR

A rack ground bus bar (RGB) may be installed within an equipment rack or cabinet to provide a termination point for individual equipment grounding conductors for equipment installed within that rack or cabinet. The rack or cabinet grounding conductor(s) may also terminate on the RGB. Installations of a cabinet or assembly of cabinets comprising one enclosure that contains a complete system may have a single RGB installed serving as the system ground bus.

5.3.3.1 SPECIFICATIONS AND BONDING REQUIREMENTS

The RGB **shall** be made of solid copper, copper alloy, tinned copper, or tinned steel. The RGB **shall** be sized appropriately for the application and **shall** be sized equivalent to no less than 35 mm^2 csa (#2 AWG) copper conductor. The bus bar **shall** have a suitable number of drilled 11 mm (0.4375 in.) holes to accommodate the required number of connections.

The installation specifications for the RGB and the acceptable methods for bonding the RGB back to the site's grounding system are listed below.

- The RGB **shall** be securely mounted on suitable standoff hardware to maintain a separation of dissimilar metals and to facilitate conductor attachment. The use of standoff insulators may be suitable for this purpose.
- The RGB may be directly mounted/bonded to the rack or cabinet frame only if doing so allows adequate space for attaching grounding conductors and does not create a dissimilar metals reaction.
- The RGB grounding conductor **shall** be made of copper and may be insulated. If the conductor is insulated, the jacket **shall** be listed for the application as described within this chapter (ANSI-J-STD-607-A-2002 and ANSI T1.334-2002).
- The RGB grounding conductor **shall** be a minimum 35 mm^2 csa (#2 AWG) or coarser, in conductor size.
- The RGB grounding conductor should be secured to the RGB by listed two-hole compression lug. See “Bonding to the MGB, SSGB And RGB” on page 5-36.
- The RGB grounding conductor should be free of splices. Should a splice in the grounding conductor become necessary, splicing **shall** be permitted only by listed irreversible compression-type connectors or by exothermic welding (NFPA 70-2005, Article 250.64(C)).
- The RGB grounding conductor **shall** be bonded back to the MGB, a co-located SSGB, an equipment ground bus conductor, or an equipment ground bus extension conductor as described within this chapter.
- At stand-alone cabinet or cabinet assembly installations where no MGB or SSGB is installed, the RGB **shall** be bonded to the electrical service grounding electrode system or conductor with an exothermic weld or a listed irreversible compression-type connection device.

5.3.4 GROUNDING (EARTHING) CONDUCTORS

All interior grounding (earthing) and bonding conductors **shall** be insulated stranded copper conductors unless otherwise specified within this chapter. Insulated conductors **shall** be listed for the space in which they are intended to be placed. The jacket **shall** be green, green with a yellow stripe or properly marked with a distinctive green coloring, green tape or green adhesive label (NFPA 70-2005, Article 250.119(A) and ANSI-J-STD-607-A-2002).

NOTE: Conductors installed within a plenum **shall** be compliant with NFPA 70-2005, Article 300.22 and cables installed within Information Technology rooms **shall** be compliant with NFPA 70-2005, Article 645. Ground conductors **shall** have an approved covering (insulation) or may be bare. When bare conductors are used they **shall** be solidly supported on suitable standoff insulators at intervals of no more than 610 mm (24 in.). These conductors **shall not** be in contact with metallic surfaces or other conductors unless intended to be bonded to these surfaces or conductors. These conductors **shall** be covered or jacketed upon exit from the plenum area and may be spliced at this point using an approved splicing method described within this chapter.

All grounding conductors **shall** be installed and routed so that personal safety is not compromised and that all equipment is serviceable. The following requirements **shall** apply:

- **Length**: conductors **shall** be no longer than required to achieve their purpose and **shall** be installed and routed in a professional and workmanlike manner.
- **Support**: conductors **shall** be secured or attached to surfaces as required to ensure they do not become damaged or disconnected. Conductors **shall** be secured in a manner that permits associated equipment to be easily serviced. Conductors **shall** be secured at no greater than 914 mm (3 ft.) intervals.
- **Protection**: conductors installed in areas where they may be subjected to damage **shall** be sleeved in electrical non-metallic tubing, or other conduit, that is securely attached to the surface over which it is routed.
    - In locations where metallic tubing or conduit is required for adequate protection, the conductor(s) routed through the metallic tubing or conduct must be effectively bonded to each end of the conduit using suitable listed means and devices (NFPA 70-2005, Articles 250.92 (A)(3) and 250.64(E)).
    - When ground conductor tap joints are used, they **shall** be properly insulated as to prevent the bare conductor or connection device from making incidental contact with metallic surfaces.
- **Routing**:
    - At points where conductors are routed through holes within metallic surfaces, the surfaces **shall** be suitably protected with grommets or other material to minimize damage to the conductor or insulation.
    - Conductors **shall** be routed toward the MGB, SSGB, or RGB. Connections to bus conductors **shall** always be made with the tap conductors routed toward the MGB, SSGB, or RGB. See Figure 5-1 on page 5-4 and Figure 5-17 on page 5-24.
    - At points where conductors must pass through a hole in a metallic surface and the hole is slightly larger than the conductor, the conductor **shall** be bonded to the metallic surface through which it passes. If the hole or opening is much larger than the conductor and is intended to accommodate several conductors, the conductor is not required to be bonded. See Figure 5-14 on page 5-22.
    - Ground bus conductors may be routed within cable trays, on the outside of cable trays where suitable support is provided, or along equipment platforms. See Figure 5-15 and Figure 5-16 on page 5-23.
    - Equipment grounding conductors **shall** be installed along the rack rail or other suitable support medium leading to the cable tray system or ground bus conductor.

- Ground bus conductors **shall** be routed using the shortest possible routes. They may extend into an adjoining subsystem equipment area and may serve as the grounding conductor for a SSGB or a RGB. These ground bus conductors may have ground bus extension conductors to provide a ground bus within cross section segments of a cable tray system. These ground bus extension conductors **shall** be of the same specification as the ground bus conductor and **shall** be routed with all connections to the ground bus conductor pointed in the direction of the MGB or SSGB.

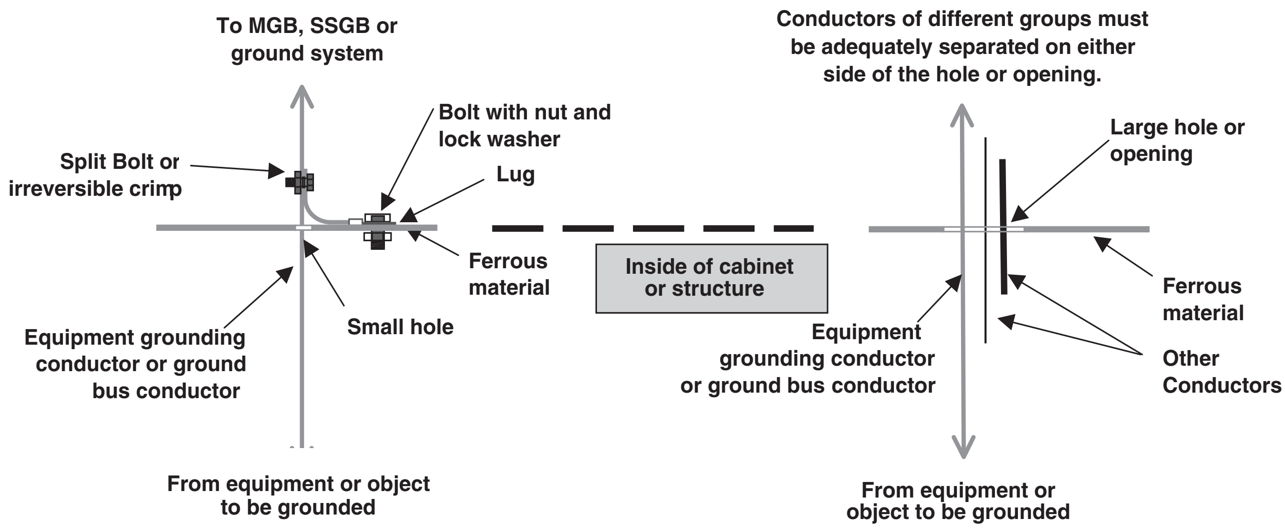


FIGURE 5-14 CONDUCTOR ROUTING THROUGH HOLES OR OPENINGS IN METALLIC SURFACES

- **Bending radius**: Ground bus conductors of all sizes **shall** maintain a minimum bending radius of 203 mm (8 in.). The angle of any bend **shall not** be less than 90 degrees (NFPA 780-2004, Section 4-9.5). See Figure 5-13 on page 5-19.
- **Separation**:
  - All ground conductors **shall** be separated a minimum of 51 mm (2 in.) from conductors of other cable groups as defined in “Cable Trays” on page 3-18, and “Cable Separation and Grouping within Racks and Cabinets” on page 9-12. Grounding conductors may come in contact with other cable groups if they cross at a 90 degree angle and the crossing angle can be maintained. An exception may be when conductors are grouped together to enter or exit a cabinet or enclosure. Grouping only at this point is acceptable, provided the conductors are suitably separated on either side of the opening.
  - To minimize potential inductive effects when routing a grounding conductor through ferrous material, the conductor **shall** be separated from the ferrous material by a distance of at least 51 mm (2 in.) where achievable, or the grounding conductor **shall** be effectively bonded to the ferrous material. See Figure 5-14.

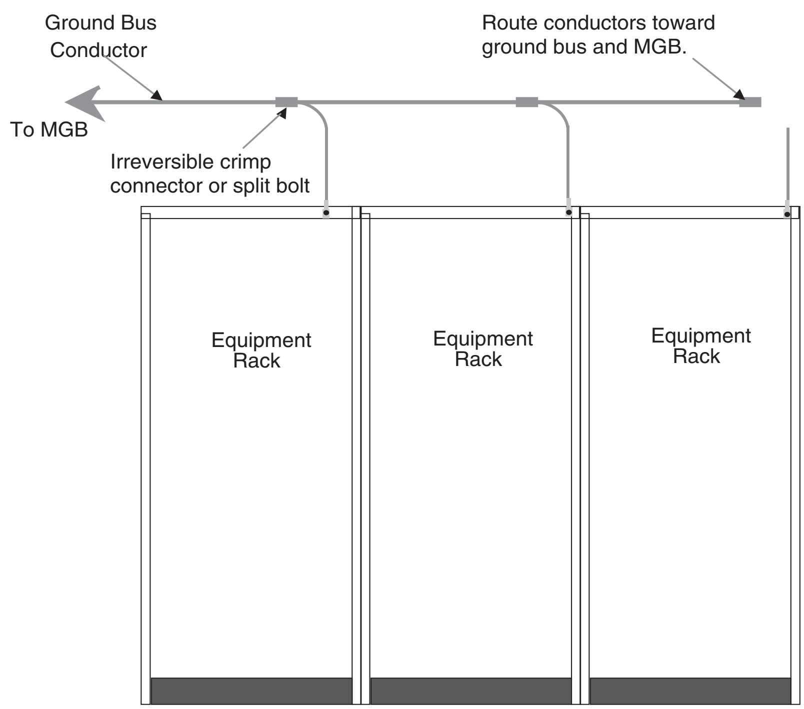


FIGURE 5-15 GROUND BUS CONDUCTOR ROUTING

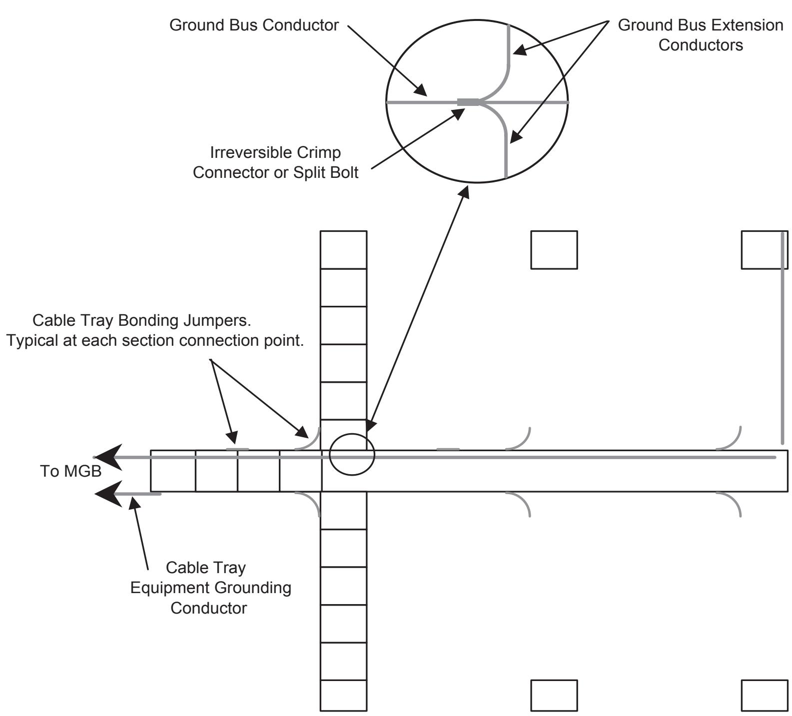


FIGURE 5-16 GROUND BUS CONDUCTOR ROUTING - TOP VIEW OF CABLE TRAYS

5.3.5 GROUND (EARTH) BUS CONDUCTORS

Ground (earth) bus conductors interconnect the MGB, SSGB, RGB and the equipment grounding conductor with the cabinets, racks or individual system or subsystem components. The end of the conductor opposite the MGB or SSGB typically remains unterminated, although this end of the conductor may be terminated to a cabinet, rack, individual system component or RGB.

Ground bus conductors typically originate at the MGB and radiate throughout the equipment area generally within the cable tray system. These conductors may extend into an adjoining subsystem equipment area and may serve as the grounding conductor for a SSGB, or RGB. Ground bus conductors **shall** be bonded to the MGB, SSGB, or RGB using methods described within this chapter.

Ground bus conductors may have ground bus extension conductors to provide a ground bus within cross section segments of a cable tray system. These ground bus extension conductors **shall** be of the same specification as the ground bus conductor and **shall** be routed with all connections to the ground bus conductor pointed in the direction of the MGB or SSGB. The ground bus extension conductor **shall** be bonded to the ground bus conductor using suitable methods described within this chapter.

Equipment grounding conductors from each cabinet, rack or individual system component chassis **shall** be bonded to the ground bus conductor or ground bus extension conductor using methods described within this chapter. See Figure 5-17. Ground bus conductors are not required to be installed at all locations, provided that equipment grounding conductors from each cabinet, rack and individual system component extend to the MGB or SSGB.

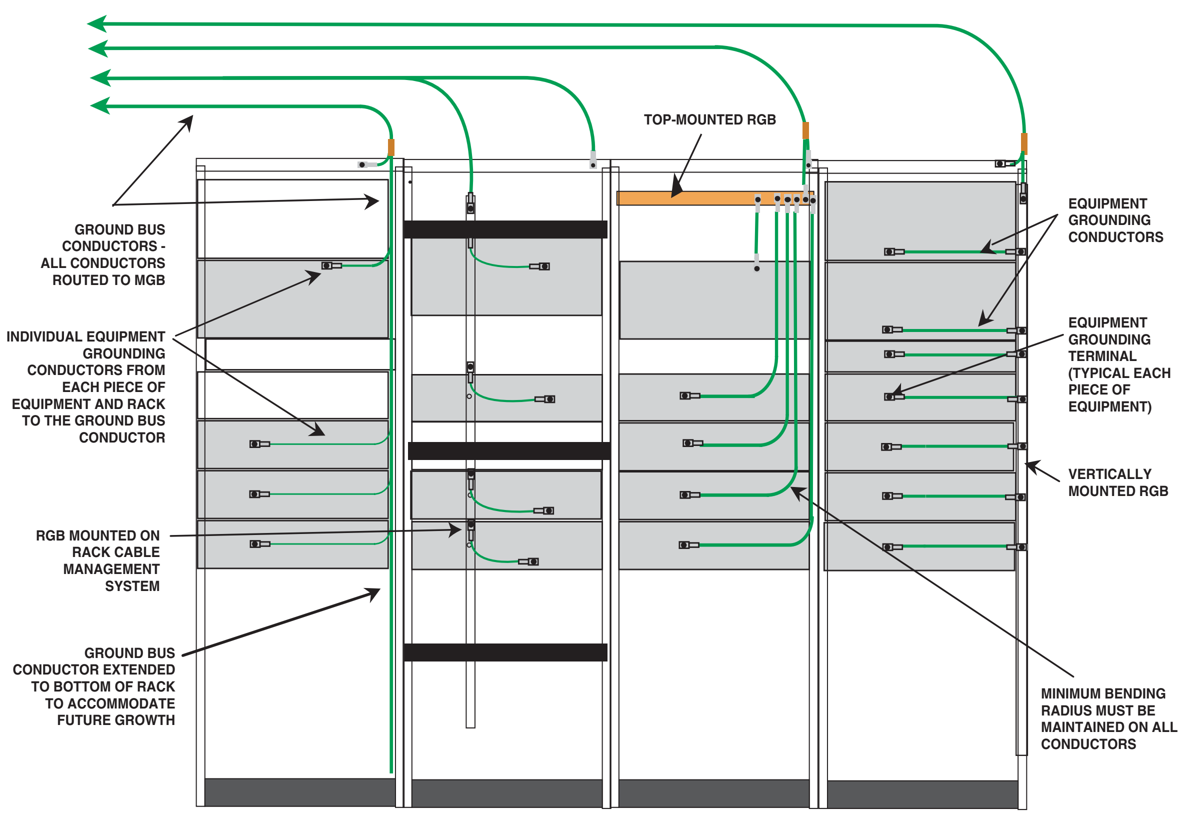


FIGURE 5-17 ACCEPTABLE METHODS FOR BONDING FROM THE EQUIPMENT TO THE MGB

5.3.5.1 LOCATION

One or more ground (earth) bus conductors **shall** typically be installed within the cable tray system above or below the equipment rows, as required by equipment layout and cable tray configuration. Typically one ground bus conductor is installed in each cable tray running the length of the equipment area. Each equipment row **shall** have a ground bus conductor installed in each cable tray cross section. This conductor may be a ground bus extension conductor from the main ground bus conductor. See Figure 5-16 on page 5-23. Minimum bending radius and angle **shall** be observed.

5.3.5.2 SPECIFICATIONS

Ground (earth) bus conductors, including ground bus extension conductors, **shall** be a 35 mm^2 csa (#2 AWG) or coarser, green-jacketed, solid or stranded copper conductor. When the conductors are insulated, they **shall** be listed for the space in which they are intended to be placed and the jacket **shall** be green or properly marked with a distinctive green color (ANSI-J-STD-607-A-2002).

The length of a 35 mm^2 csa (#2 AWG) ground bus conductor should not exceed 10 m (33 ft.). If a greater conductor length is required, the conductor should be sized at 2 kcmil per linear ft. of conductor length up to a maximum size of 95 mm^2 csa (#3/0 AWG). For conductor sizing requirements, see Table 5-3 and Table 5-4 on page 5-27 (ANSI-J-STD-607-A-2002 and MIL-HDBK-419A).

For specific applications a copper bus bar of equal or larger size may be used. An example of such an application is a bus bar mounted from bottom to top of an equipment rack or cabinet, with individual equipment ground connections suitably attached to the bar.

5.3.6 COMMUNICATION BONDING BACKBONE CONDUCTOR AND GROUNDING (EARTHING) EQUALIZER CONDUCTORS

A communication bonding backbone conductor is used to interconnect multiple equipment areas within small, large and multistory buildings. This type of conductor is similar to a ground (earth) bus conductor in that it is used to interconnect all main SSGBs on each floor or within each equipment room to the MGB. The intended function of the communication bonding backbone conductor is to reduce or equalize potential differences between all interconnected communication systems within the building.

When two or more communication bonding backbone conductors are used within a large or multistory building, the communication bonding backbone conductors are bonded together with grounding equalizer conductors as described within this chapter to equalize potential differences between the separate communication bonding backbone conductors and each equipment area's main SSGBs within the building.

5.3.6.1 LOCATION

The communication bonding backbone conductor originates at the building's main grounding (earthing) electrode bonding location and extends throughout the building within telecommunication cable pathways. The pathways **shall** be configured to maintain proper cable group separation from other cable groups and address routing to minimize the lengths of the communication bonding backbone conductor. The end of the conductor opposite the building's main grounding electrode bonding location typically remains unterminated, although this end of the conductor may be terminated directly to the furthest SSGB as described within this chapter.

Depending on the building construction, building size, communication system requirements, and the telecommunication cable pathways, one or more communication bonding backbone conductors may be installed. Each communication bonding backbone conductor **shall** be consistent with the design of the communication bonding backbone cabling system, and it **shall** be installed so that it is protected from physical damage.

Typically when the equipment rooms or areas are located on different floors of a large multi-story building, a separate communication bonding backbone conductor is routed up each of the opposite sides of the building. To equalize potential, the communication bonding backbone conductors are bonded together with a grounding equalizer conductor at the top floor and at a minimum of every third floor in between using methods described within this chapter (ANSI-J-STD-607-A-2002).

5.3.6.2 SPECIFICATIONS

All communication bonding backbone conductors and grounding (earthing) equalizer conductors **shall** be established of 35 mm^2 csa (#2 AWG) or coarser, solid or stranded copper conductor. When the conductors are jacketed, they **shall** be listed for the space in which they are intended to be placed and the jacket **shall** be green or properly marked with a distinctive green color (ANSI-J-STD-607-A-2002).

In the buildings that do not have effectively bonded structural steel, additional conductor sizing should be considered. All communication bonding backbone conductors and grounding equalizer conductors **shall** be of the same size. The linear length of a 35 mm^2 csa (#2 AWG) communication bonding backbone conductor or a grounding equalizer conductor should not exceed 10 m (33 ft.). If a greater conductor length is required, these conductors should be sized at 2 kcmil per linear foot of conductor length up to a maximum size of 95 mm^2 csa (#3/0 AWG). See Table 5-3 and Table 5-4 on page 5-27 for conductor sizing requirements (ANSI-J-STD-607-A-2002; MIL-HDBK-419A).

All communication bonding backbone conductors and grounding equalizer conductors should be installed without splices. When splices are necessary, the number of splices **shall** be kept to a minimum and the splices **shall** be accessible and located in telecommunication spaces (ANSI-J-STD-607-A-2002). All communication bonding backbone and grounding equalizer conductor splices **shall** be established using suitable methods described within the chapter.

NOTE: The interior water piping system of the building and metallic cable shields **shall not** be used as communication bonding backbone conductors or grounding equalizer conductors (ANSI-J-STD-607-A-2002).

Each equipment area's main SSGB **shall** be bonded to the communication bonding backbone conductor or to the grounding equalizer conductor with a grounding conductor of the same size as the communication bonding backbone conductor using suitable methods described within this chapter. The building's MGB **shall** be bonded to the service equipment (power) grounding electrode system using a grounding conductor of the same size as the communication bonding backbone conductor by using suitable methods described within this chapter (ANSI-J-STD-607-A-2002).

TABLE 5-3 SIZING OF GROUND BUS CONDUCTORS

Conductor length in linear m (ft)	Conductor size in mm^2 csa (AWG / MCM)
Less than 10 (33)	33.62 (2)
10 – 13 (34 – 41)	42.41 (1)
13 – 16 (42 – 52)	53.49 (1/0)
16 – 20 (53 – 66)	67.43 (2/0)
20 – 25 (67 – 84)	85.01 (3/0)[1]
25 – 32 (85 – 105)	107.26 (4/0)
32 – 38 (106 – 125)	126.70 (250 MCM)
38 – 53 (126 – 175)	177.39 (350 MCM)
53 – 76 (176 – 250)	253.35 (500 MCM)
Greater than 114 (251 – 375)	380.13 (750 MCM)

1. Maximum wire size required by this standard. The remaining five wire sizes shown are recommendations for the given respective lengths.

TABLE 5-4 STANDARD WIRE SIZES AVAILABLE FOR INTERNATIONAL MARKET

Conductor size in mm^2 csa	Conductor size in AWG / MCM
6	10
10	8
16	6
25	4
35	2
50	1/0
75	2/0
95	3/0
120	4/0
150	300 MCM
185	350 MCM
240	500 MCM
300	600 MCM
400	800 MCM

5.3.7 INTERNAL PERIMETER GROUND (EARTH) BUS CONDUCTORS

The internal perimeter ground (earth) bus (IPGB) provides a suitable grounding conductor to the MGB for ancillary support apparatus, electrical conduits and other metallic items that may be located throughout the shelter, building or room. It is essential that all ancillary metallic items within the area be bonded to the single point ground established by the MGB or SSGB.

An internal perimeter ground bus conductor should be installed in all equipment shelters, buildings or rooms specifically designed or designated for communications equipment, or a generator or power distribution room. Motorola recommends an IPGB whenever a tower is associated with the site. An internal perimeter ground bus conductor is not required in rooms or areas that are within a larger building where ancillary support apparatus (non-electronic equipment) is not present or where it is more practical to bond this support apparatus to the MGB or SSGB with individual equipment grounding conductors. An internal perimeter ground bus conductor may be installed in areas where there is a need to bond several items of support apparatus to the MGB or SSGB regardless to the specific usage of the area.

CAUTION

The internal perimeter ground bus conductor shall not be used for bonding communications equipment such as cabinets, racks, chassis or equipment grounding conductors to the MGB (ANSI T1.334-2002).

5.3.7.1 LOCATION AND INSTALLATION

When used, the internal perimeter ground (earth) bus **shall** be installed such that it encompasses the interior of the shelter, building, room or area with two independently separate ground bus conductors on opposite sides of the room. Each of these conductors **shall** be located horizontally along the wall, approximately 2.4 m (8 ft.) above the finished floor or within 305 mm (1 ft.) below the ceiling and terminated to the MGB or SSGB, as applicable, at one end only, using methods described within this chapter. The two bus conductors should met at a point within the equipment area and approximately opposite the location of the MGB. At the location where the two bus conductors meet, the bus conductors **shall** be separated by a minimum distance of 104 mm (4 in.). See Figure 5-1 on page 5-4 for an example of this type of configuration.

The conductors **shall** be supported approximately 51 mm (2 in.) from the wall surface on insulated standoffs. Standoffs **shall** be installed at approximately 610 mm (2 ft.) intervals or as necessary to keep the conductor securely in place without noticeable sags and bends. Where transmission lines enter the equipment area at a lower point along the wall or through the floor or ceiling and the MGB is suitably located lower on the wall or on the floor or ceiling, the internal perimeter ground bus conductors **shall** be routed as stated above, with the following exception: at a point where these conductors can be readily connected to the MGB or SSGB, these conductors **shall** be routed across the ceiling or downward along the wall and connected to the MGB or SSGB; a vertical cable ladder of suitable design may be used for protection and support.

5.3.7.2 SPECIFICATIONS

The internal perimeter ground (earth) bus conductors **shall** be a 35 mm^2 csa (#2 AWG) or coarser copper conductor, free of splices. When the conductors are insulated, they **shall** be listed for the space in which they are intended to be placed and the jacket **shall** be green or properly marked with a distinctive green color (ANSI-J-STD-607-A-2002). If a splice in the bus conductor is unavoidable, it **shall** be exothermically welded or spliced using a listed irreversible connection. It is desirable that this conductor be stranded for better flexibility and ease of installation and maintenance. However, this conductor may be a solid conductor, copper bus bar, or copper strap of equal or larger surface area.

5.3.8 EQUIPMENT GROUNDING (EARTHING) CONDUCTORS

An equipment grounding (earthing) conductor bonds equipment chassis or frames, and metallic ancillary support apparatus to the internal grounding system. An equipment grounding conductor from each piece of electronic equipment **shall** be bonded to the MGB, SSGB, RGB, ground bus conductor or ground bus extension using suitable methods described within this chapter. An equipment grounding conductor from each piece of ancillary support apparatus **shall** be bonded to the MGB, SSGB or internal perimeter ground bus (IPGB) conductor using suitable methods described within this chapter.

NOTE: Braided conductors **shall not** be used at any location.

5.3.8.1 LOCATION

The equipment grounding (earthing) conductor for electronic equipment **shall** be suitably supported. One end of the conductor **shall** be bonded to the equipment or support apparatus using methods described within this chapter. The other end of the conductor **shall** be bonded to the ground bus conductor, RGB, SSGB, or MGB using suitable methods described within this chapter. See Figure 5-17 on page 5-24.

5.3.8.2 SPECIFICATIONS

The equipment grounding (earthing) conductor **shall** be a 16 mm^2 csa (#6 AWG) or larger, green-jacketed, solid or stranded copper conductor. A stranded conductor may be more desirable due to the ease of installation and maintainability. If the equipment grounding conductor length must exceed 4 m (13 ft.) before it terminates to a ground bus conductor, RGB, SSGB, or MGB, the conductor **shall** be sized according to Table 5-5.

TABLE 5-5 SIZING OF GROUND BUS CONDUCTORS

Conductor length in linear m (ft)	Conductor size in mm^2 csa (AWG)	International Conductor size (mm^2 csa)
Less than 4 (13)	13.30 (6)	16
4 – 6 (14 – 20)	21.15 (4)	25
6 – 8 (21 – 26)	26.67 (3)	30
8 – 10 (27 – 33)	33.62 (2)	35

5.3.9 BONDING JUMPERS

A bonding jumper is used to ensure an electrically conductive path between components. Examples include sections of a cable tray which are required to be bonded together, or sections of structural steel, roof trusses, piping systems, conduits or other metallic surfaces that are required to be bonded together to maintain electrical conductivity. A bonding jumper **shall not** be used in lieu of an equipment grounding (earthing) conductor.

5.3.9.1 LOCATION

Bonding jumpers **shall** be installed to bond components of the same or similar structure together. The location will be dependent on the specific application. Bonding jumpers **shall** be as short as possible, **shall** be routed in as straight a line as possible, and **shall** be as free from bends as is practicable. Care **shall** be taken to ensure that attachment points are clean and free of paint, corrosion or non-conductive materials. Suitable listed lugs **shall** be used to facilitate attachment to the components as described within this chapter. See Figure 5-18 for an example of for an example of a cable tray section bonding jumper.

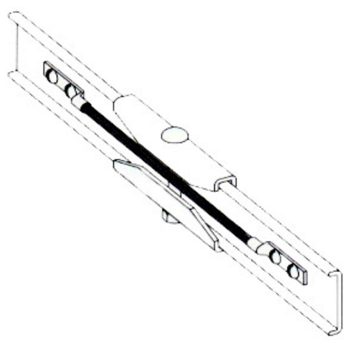


FIGURE 5-18 BONDING CABLE TRAY SECTIONS

5.3.9.2 SPECIFICATIONS

Bonding jumpers **shall** be 16 mm^2 csa (#6 AWG) or coarser, solid or stranded copper conductor. A stranded conductor may be more desirable due to the ease of installation and maintainability. When the conductors are insulated, they **shall** be listed for the space in which they are intended to be placed and the jacket **shall** be green or properly marked with a distinctive green color (ANSI-J-STD-607-A-2002 and NFPA 70-2005, Article 250.119). When bonding jumpers are installed outside a raceway or enclosure, their conductor length **shall not** exceed 1.8 m (6 ft.) (NFPA 70-2005, Article 250.102(E)).

5.4 CONNECTION METHODS FOR INTERNAL GROUNDING (EARTHING) SYSTEM

All components of the internal grounding (earthing) system and all equipment and ancillary support apparatus including, but not limited to, items listed in Table 5-6 on page 5-40 **shall** be effectively bonded together by using the following requirements and connection methods described within this chapter:

- General bonding requirements
- Bonding to equipment and ancillary support apparatus
- Bonding to the MGB
- Bonding to SSGB
- Bonding to RGB
- Bonding to ground bus conductor
- Bonding to communication bonding backbone conductors and grounding equalizer conductors

5.4.1 GENERAL BONDING REQUIREMENTS

The following requirements **shall** apply when attaching conductors to equipment, ancillary support apparatus, ground (earth) bus bars, and when attaching one conductor to another.

- Only connection devices that require the complete removal of the conductor jacket or insulation and result in a connection to the complete conductor surface area **shall** be suitable for use.
- All mechanical and compression-type connection devices **shall** be UL 486A listed and of the proper size for the application. These connection devices **shall** be tin-plated when connected with steel, galvanized steel or aluminum surfaces.
- All clamps and compression-type connection devices **shall** be UL 486A listed and **shall** maintain a minimum 88% conductivity rating.
- Compression systems **shall** include crimped die index and company logo for purposes of inspection.
- Listed two-hole, long barrel, compression lugs are preferred over single-hole lugs and **shall** be required where two-hole lugs are referenced within this chapter.
- No more than one clamp, fitting or lug may be attached by the same bolt or bolts. An exception to this is when a jumper from a terminal strip or other internal connection point of the same equipment must be bonded to the equipment grounding conductor.
- No more than one conductor **shall** be connected by a single clamp, fitting or lug unless the clamp, fitting, or lug is listed for multiple conductors.
- Solid conductors **shall** be attached to lugs and to other conductors by irreversible high compression crimping process. Only listed irreversible compression type lugs and connection devices **shall** be used.
- Connections between dissimilar metals **shall not** be made unless the conductors are separated by a suitable material that is a part of the attachment device. Only attachment devices listed and approved for use with the specific dissimilar metals may be used for this purpose.

- An appropriate type of listed, conductive anti-oxidant **shall** be applied on all connections of dissimilar metals. Copper enhanced anti-oxidant compound should be used between copper, brass, bronze and tin-plated bonding surfaces. Zinc enhanced anti-oxidant compound should be used between tin-plated connection devices and steel, galvanized steel, zinc-chromate steel, aluminum, and tin-plated copper bus bar bonding surfaces.
- Where threaded or tapped holes are provided for attachment purposes, a star or split type lock washer **shall** be installed under the head of the screw or bolt and/ or between the nut and the ground bus bar. See Figure 5-19 on page 5-32 for the correct location of the star or split washer in these instances.
- Self-tapping or sheet metal type screws **shall not** be used for attaching ground or grounding conductors to any surface. (See NFPA 70-2005, Article 250.8 for additional information.)
- Paint, enamel, lacquer, or other nonconductive coatings **shall** be removed from threads and surface areas where connections are made (NFPA 70-2005, Article 250.12). Use of a star washer **shall not** alleviate the requirement to remove nonconductive coatings from attachment surfaces. Star or split type washers **shall not** be installed between the conductive surfaces. Proper placement of lockwasher is shown in Figure 5-19.

NOTE: Do not install a washer of any kind between the ground lug and the bonding surface.

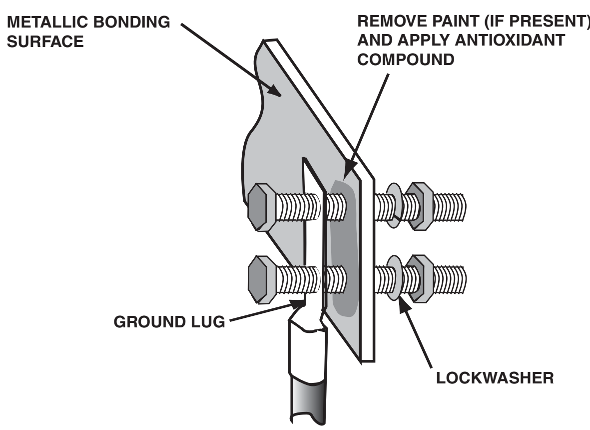


FIGURE 5-19 PROPER LOCATION OF WASHER WHEN CONNECTING GROUND LUG

- All two-hole lugs **shall** have bolts in both holes with lock washers placed on the nut side of the bonding surface.
- All securing hardware for mechanically bolted clamps and lugs **shall** be stainless steel or approved for the application.

The following methods of connection are **unacceptable** and **shall not** be used:

- Insulation piercing connectors.
- Self-tapping or sheet metal type screws **shall not** be used to provide continuous and permanent electrical bonds (NFPA 70-2005, Article 250.8 and FAA-STD-019d-2002).
- Tinnerman or similar type clips (FAA-STD-019d-2002).
- Aluminum connection devices.

- Star or split washers **shall not** be installed between conductive surfaces. These washers may be used only under the head and/or nut of the bolt as shown in Figure 5-19.
- The series or daisy chain method of connecting a conductor from one piece of equipment to another and then to the ground bus conductor **shall not** be permitted (FAA-STD-019d-2002). The series or daisy chain method refers to any method of connection whereby the conductors are connected from one chassis, equipment frame or rack connection point to a second chassis, equipment frame or rack connection point and on to a third connection point, creating a series arrangement whereby the removal of the second connection point interrupts the ground path from the first chassis, equipment frame or rack. See Figure 5-20 on page 5-34.
- When attaching two conductors together, or attaching a conductor to a lug, connections **shall not** depend solely on solder (NFPA 70-2005, Articles 250.8 and 250.70) although properly crimped connections may be soldered.
- Crimp connections **shall not** be used on solid conductors unless they are listed and approved for the application.
- Mechanical lugs and clamps (such as set screw lug or clamp) **shall not** be used on solid conductor.
- Conductors **shall not** extend through or beyond the clamp, fitting or lug unless the device is designed and listed to permit this conductor extension.
- Braided conductors **shall not** be used as a ground bus or equipment grounding conductor at any location (FAA-STD-019d-2002).

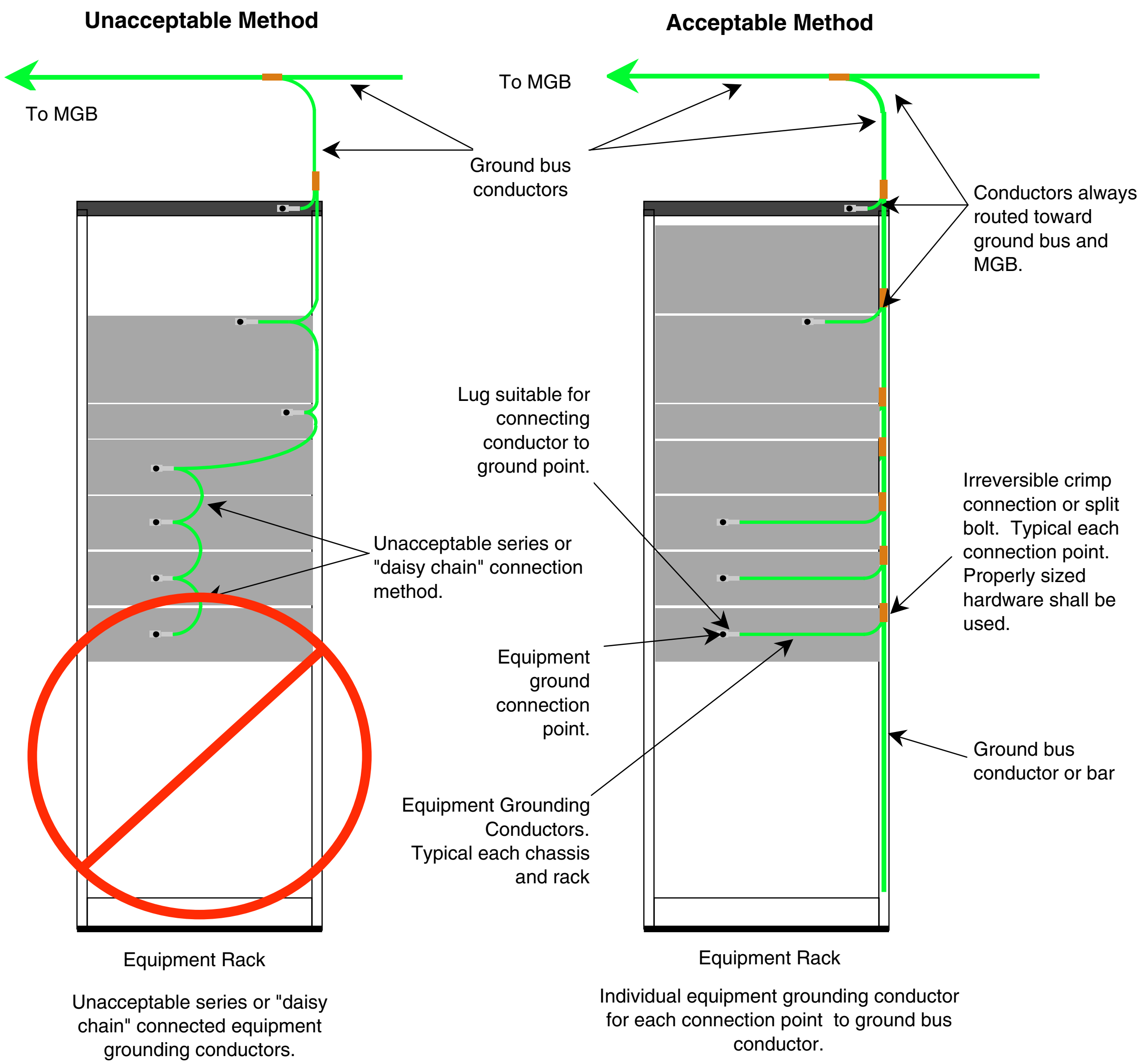


FIGURE 5-20 DAISY CHAIN GROUNDING NOT ALLOWED

5.4.2 BONDING TO EQUIPMENT AND ANCILLARY SUPPORT APPARATUS

All applicable general and below bonding requirements **shall** apply when attaching equipment grounding (earthing) conductors to equipment and ancillary support apparatus:

- Each electronic equipment chassis **shall** have a separate and independent equipment grounding conductor.
- Paint, enamel, lacquer and other electrically non-conductive coatings **shall** be completely removed from threads and bonding surface areas to ensure good electrical continuity (NFPA 70-2005, Article 250.12).

NOTE: Use of a star washer does not alleviate the requirement to remove non-conductive coatings from attachment surfaces because the star washer does not provide enough contact surface area.

- Connections to steel and galvanized steel pipes, conduit or other round member items **shall** be made using a UL 486A listed, bolted clamp with stainless steel securing hardware or other suitable listed means. In high humidity areas, the clamps **shall** be stainless steel or tin-plated UL 486A listed to prevent galvanic corrosion.
- Connections to vibrating or moveable items **shall** be made by using an exothermic weld or a compression-type two-hole lug.
- Connections to structural building steel **shall** be made by using an exothermic weld, listed irreversible high compression-type connection, or listed tin-plated flange-type bonding connector that is equipped with two securing bolts. Figure 5-21 shows examples of flange-type bonding connectors.

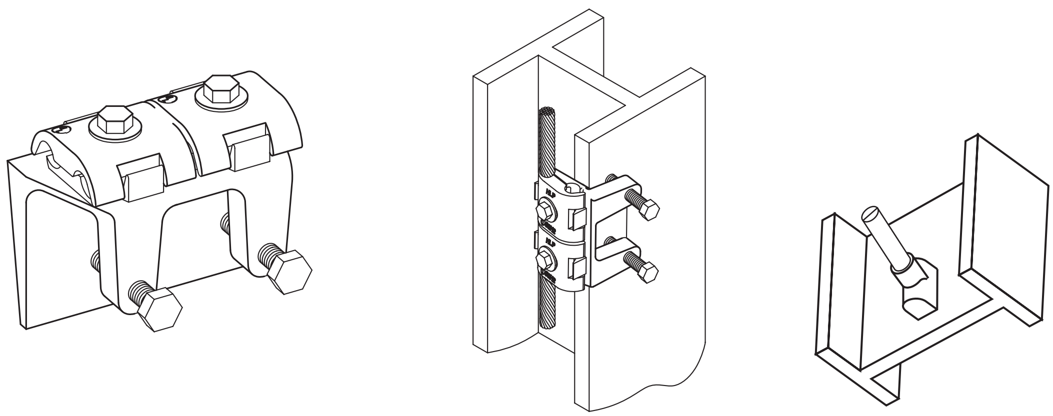


FIGURE 5-21 ACCEPTABLE BUILDING STEEL BONDING CONNECTIONS

- Connections to raised flooring support system **shall** be made using a tin-plated listed compression lug, listed pedestal clamp, or exothermic welding. Where practical the lug should be effectively bonded to the pedestal's upper support plate or to cross connecting stringer. Figure 5-22 shows some examples of acceptable pedestal bonding configurations.

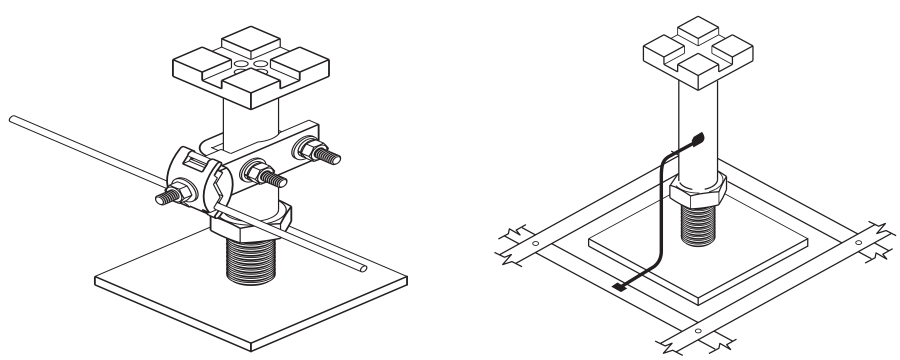


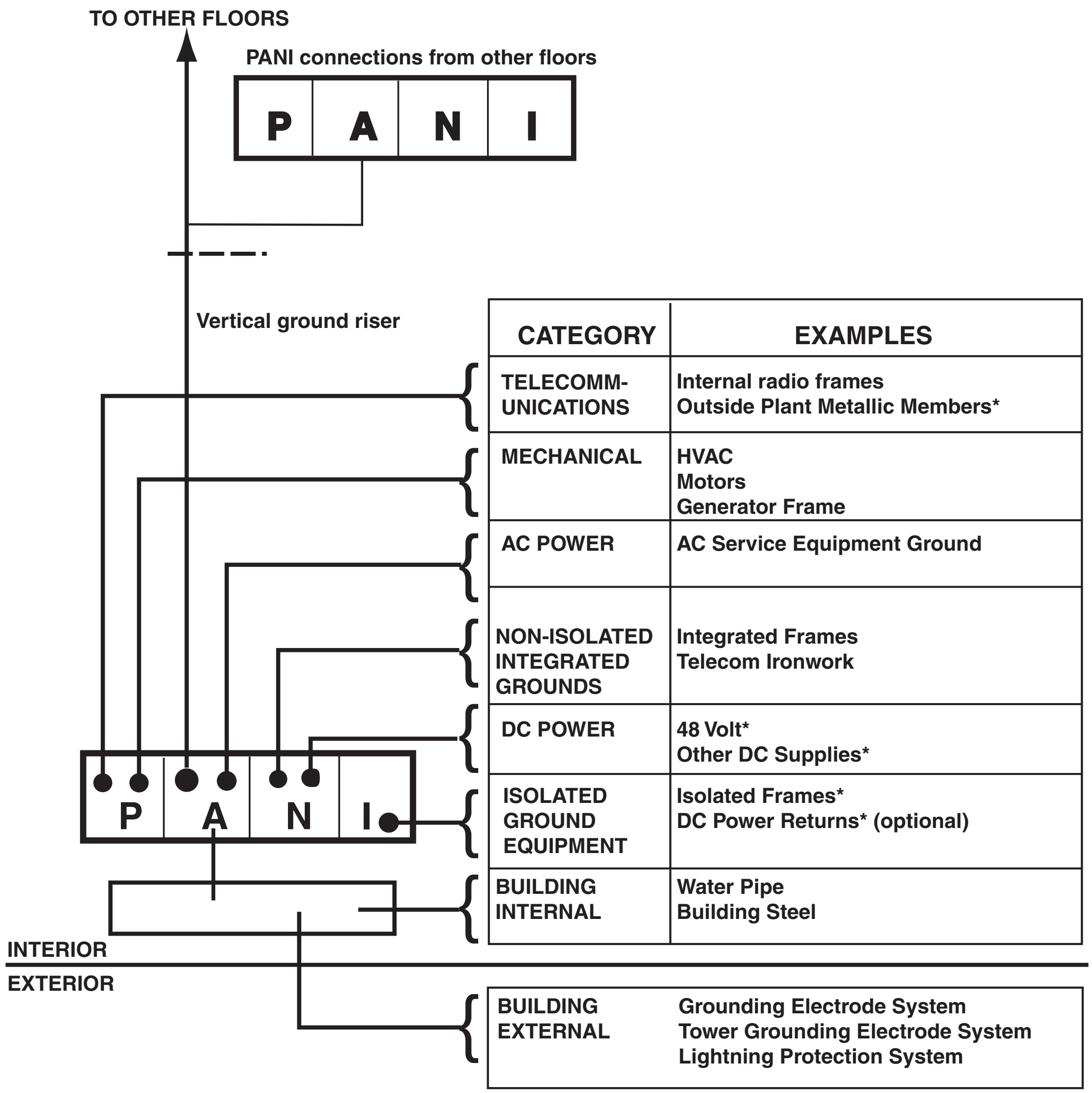
FIGURE 5-22 ACCEPTABLE RAISED FLOORING BONDING CONNECTIONS

5.4.3 BONDING TO THE MGB, SSGB AND RGB

All applicable general bonding requirements and the bonding requirements listed below **shall** apply when attaching grounding (earthing) conductors, grounding electrode conductors, ground bus conductors and equipment grounding conductors to the MGB, SSGB or RGB:

- The MGB grounding conductor(s) **shall** be installed using the shortest and straightest downward-flowing path toward the earth and the grounding electrode system. For examples of grounding conductor routing requirements see Figure 5-8 on page 5-12 and Figure 5-9 on page 5-14.
- All ground bus conductors and equipment grounding conductors bonded directly to the MGB, SSGB or RGB **shall** have a direct path back toward the grounding electrode system.
- Connection of a grounding conductor, grounding electrode conductor, communication bonding backbone conductor and ground bus conductor to the MGB or SSGB **shall** utilize exothermic welding, listed irreversible compression-type connection or listed compression two-hole lug and securing hardware of the proper size for the application unless otherwise specified within this chapter (ANSI-J-STD-607-A-2002).
- Connection of a grounding conductor, grounding electrode conductor and ground bus conductor to the RGB **shall** utilize exothermic welding, listed irreversible compression-type connection, or listed compression lug and securing hardware of the proper size for the application. Listed compression two-hole lugs are preferred.
- Connection of an equipment grounding conductor to the MGB, SSGB or RGB **shall** utilize exothermic welding, listed irreversible compression-type connection, listed compression lug, or listed pressure lug and securing hardware of the proper size for the application. Listed compression two-hole lugs are preferred (ANSI-J-STD-607-A-2002).
- Grounding materials should be of copper or copper alloy. Where other materials are used in conjunction with copper or copper alloy, care **shall** be exercised in providing proper bimetallic couplings to reduce the possibility of galvanic corrosion (ANSI T1.334-2002; ANSI T1.313-2003).
- It is desirable for the MGB, SSGB, and RGB to be electrotin-plated for reduced contact resistance. If not electrotin-plated, the bus bar bonding surface **shall** be cleaned prior to fastening the conductor's connection device. An appropriate type of listed conductive anti-oxidant compound should be applied to the contact area to control corrosion and reduce contact resistance of mechanical and compression-type connections.

Some customers such as cellular operators may require that conductors be bonded to the MGB in a specific sequence or order determined by the conductor's origin or the type of equipment being bonded to the MGB. One of these methods, known as PANI, allocates specific areas of the MGB for bonding surge energy **P**roducers, **A**bsorbers, **N**on-isolated equipment, and **I**solated equipment. An example of this type of configuration is shown in Figure 5-23 and Figure 5-24. This method is not required for compliance with this installation standard and is provided for reference only. See ANSI T1.313-2003 for additional information on this method of bonding to the MGB.



NOTE:
Items marked with an asterisk (*) may have ground bars associated with them.

FIGURE 5-23 PANI GROUNDING SYSTEM SEQUENCE

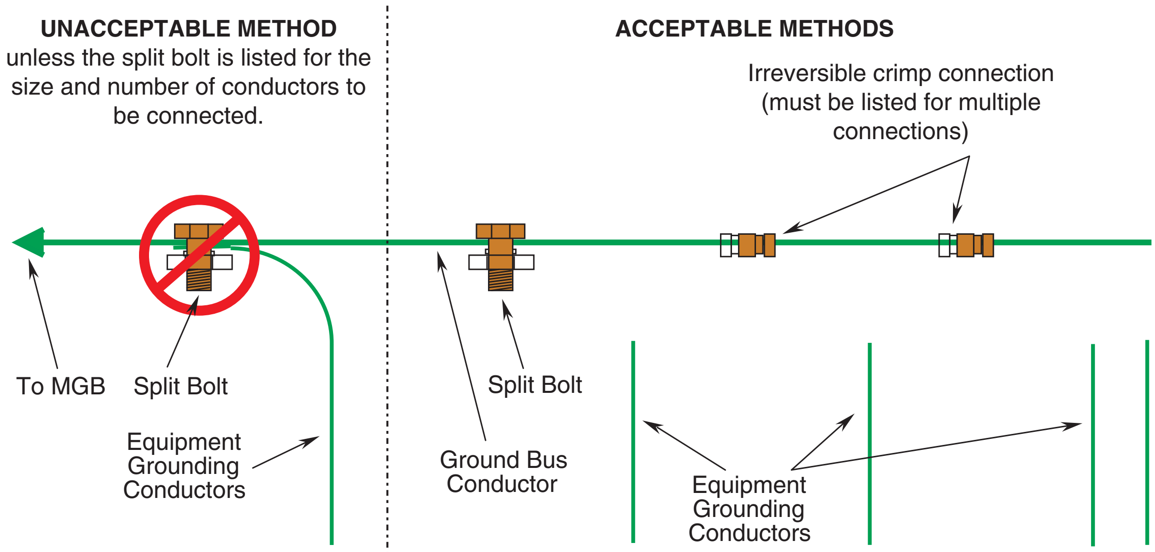
P	A	N	I
Surge Producers	**Surge Absorbers**	**Non IGZ**	**Isolated Ground Zones (IGZ)**
• RF SPD • AC Equip. • Tel. SPD • Cable Shields • ESD	• Building Steel • AC NG Bond • Water Line • Metallic Piping • Concrete Encased Electrode • Ground Rings	• +48VDC GND. • -24VDC GND. • Cable Tray Sys. • Equip. Frame • Battery Racks • Anciliary Equip.	• Logic Ground. • IG Zones

FIGURE 5-24 PANI BUS BAR CONFIGURATION

5.4.4 BONDING TO GROUND (EARTH) BUS CONDUCTORS

All applicable general bonding requirements **shall** apply when attaching ground (earth) bus extension conductors and equipment grounding conductors to a ground bus conductor. The following requirements also apply:

- All ground bus conductors should be installed without splices. Where splices are necessary, the number of splices should be kept to a minimum and they **shall** be accessible and only located in telecommunication spaces. The joined segments **shall** be connected using exothermic welding or listed irreversible compression-type connectors. All bonding joints **shall** be adequately supported and protected from damage (ANSI-J-STD-607-A-2002).
- Ground bus extension conductors **shall** always be routed toward the MGB or SSGB at the point of connection to the ground bus conductor. Ground bus extension conductors **shall** be connected to the ground bus conductor using exothermic welding or listed irreversible compression-type connectors. Connection points **shall** be taped with a suitable green tape or otherwise isolated from contact with the cable tray or other metallic surfaces.
- Equipment grounding conductors **shall** always be routed toward the MGB or SSGB at the point of connection to the ground bus conductor. Equipment grounding conductors **shall** be connected to the ground bus conductor using exothermic welding, listed compression-type connections, or listed split bolt connections. Connection points **shall** be taped with a suitable green tape or otherwise isolated from contact with the cable tray or other metallic surfaces.
- Equipment grounding conductors **shall** be connected so that the removal of a connection will not break the ground path to any other piece of equipment or ancillary support device that may have electrical power applied.
- Multiple connections **shall not** be made to one attachment point on the ground bus conductor unless this connection is made using exothermic welding, listed irreversible compression-type connector or listed split bolt. In all cases the connection means **shall** be listed for the size and number of conductors to be connected.



NOTE: Route all conductors toward the MGB.

FIGURE 5-25 BONDING TO GROUND BUS CONDUCTOR

5.4.5 BONDING TO COMMUNICATION BONDING BACKBONE CONDUCTORS AND GROUNDING (EARTHING) EQUALIZER CONDUCTORS

All applicable general bonding requirements and the requirements below **shall** apply when attaching SSGB grounding (earthing) conductors to a communication bonding backbone conductor or a grounding equalizer conductor.

NOTE: Only SSGBs should be bonded back to a communication bonding backbone conductor or a grounding equalizer conductor. All equipment and ancillary apparatus grounding conductors should be bonded back to the SSGB as described within this chapter.

- All communication bonding backbone conductors should be installed without splices. Where splices are necessary, the number of splices should be kept to a minimum and they **shall** be accessible and only located in telecommunication spaces. The joined segments **shall** be connected using exothermic welding or listed irreversible compression-type connectors. All bonding joints **shall** be adequately supported and protected from damage (ANSI-J-STD-607-A-2002).
- The bonding conductor between the SSGB and the communication bonding backbone or grounding equalizer conductor **shall** be of the same specifications as the communication bonding backbone conductor.
- The bonding conductor between the SSGB and the communication bonding backbone or grounding equalizer conductor **shall** be continuous and routed in the shortest possible straight line path back towards the MGB. If a bend is required in the SSGB bonding conductor, minimum bending radius and angle **shall** be adhered to.

- The SSGB bonding conductor **shall** be connected to the communication bonding backbone conductor or to the grounding equalizer conductor with an exothermic welding or listed irreversible compression-type connection (ANSI-J-STD-607-A-2002)
- When a grounding equalizer conductor is installed as described within this chapter, it **shall** be bonded back to the SSGBs and not to the communication bonding backbone conductors.
- The grounding equalizer conductor **shall** be connected to the SSGBs with exothermic welding, listed compression-type two-hole lugs, or listed irreversible compression type connections.
- Only the far end of a communication bonding backbone conductor may be connected directly to the SSGB. If the communication bonding conductor is connected directly to the SSGB, it **shall** be connected with exothermic welding or irreversible compression type connection. See Figure 5-4 on page 5-7 for an example of this type of grounding system configuration.

5.5 BONDING EQUIPMENT TO INTERNAL GROUNDING (EARTHING) SYSTEM

All equipment and ancillary support apparatus **shall** be bonded to the MGB, SSGB, RGB, ground (earth) bus conductor or internal perimeter ground bus (IPGB) conductor with an equipment grounding conductor as described within this chapter.

TABLE 5-6 BONDING TO THE INTERNAL GROUNDING SYSTEM FROM ITEM TOWARD EARTH

From	To					Minimum Conductor Size Unless Otherwise Specified	
Item	MGB	SSGB	RGB	Ground Bus Conductor	IPGB	35 mm^2 csa (#2 AWG)	16 mm^2 csa (#6 AWG)
SSGB	✔	✔		✔		✔	
RGB	✔	✔	✔	✔		✔	
Equipment ground bus extension	✔	✔	✔	✔		✔	
Equipment cabinet	✔	✔	✔	✔			✔
Equipment rack	✔	✔	✔	✔			
Equipment grounding conductor	✔	✔	✔	✔			✔
Individual system component chassis	✔	✔	✔	✔			✔
Control or Dispatch Centers electronic equipment and metallic parts of furniture	✔	✔	✔	✔			✔

TABLE 5-6 BONDING TO THE INTERNAL GROUNDING SYSTEM FROM ITEM TOWARD EARTH (CONTINUED)

From	To					Minimum Conductor Size Unless Otherwise Specified	
Item	MGB	SSGB	RGB	Ground Bus Conductor	IPGB	35 mm² csa (#2 AWG)	16 mm² csa (#6 AWG)
Cable tray	✔	✔					✔
Transmission line surge suppressors	✔	✔	✔	✔			✔
Primary surge suppressor	✔	✔		✔			✔
Secondary surge suppressor	✔	✔	✔	✔			✔
DC power plant	✔	✔				✔	
Separately derived AC electrical systems	✔	✔		✔		✔	
IPGB	✔	✔				✔	
Ancillary support items and metallic structural items	✔	✔			✔		✔

5.5.1 EQUIPMENT AND ANCILLARY SUPPORT APPARATUS BONDING

All equipment and ancillary support apparatus including, but not limited, to that listed below **shall** be effectively bonded back to the internal grounding system with a minimum 16 mm² csa (#6 AWG) equipment grounding conductor unless otherwise specified herein. All grounding and bonding conductors **shall** be established by using the following requirements and connection methods described within this chapter:

- Separately Derived AC Systems
- DC Power Plant
- Equipment
- Cabinets and Racks
- Cable Trays
- Ancillary Support Apparatus
- Metallic Building Structure and Piping Systems
- Surge Protection Devices

5.5.1.1 SEPARATELY DERIVED AC SYSTEMS

Separately derived AC electrical power systems have no direct electrical connection between the incoming neutral from the AC power source and the neutral conductor on the secondary side of the separately derived AC power system. Separately derived power systems can include isolation transformers, step-down or step-up transformers, generator AC power systems that are breaking the neutral conductor inside the auto transfer switch (ATS), Uninterruptible Power Supply (UPS) systems that are configured as separately derived systems, or AC inverters that are powered by a battery bank.

If a separately derived AC power system exists at the site within the communication system equipment area, a grounding conductor for the neutral to ground bond on the secondary side of the unit **shall** be bonded back to the equipment area's single point grounding system (MGB or SSGB, where the MGB is not co-located) with a 35 mm^2 csa (#2 AWG) or coarser, green-jacketed grounding conductor. Where applicable, the grounding conductor should be up-sized to meet NFPA 70-2005, Article 250.66 requirements. The grounding conductor **shall** be bonded to both locations with compression-type, two-hole, UL 486A listed lugs as described within this chapter.

If a separately derived AC power system exists at the site but not located at the communication system equipment area, a grounding conductor for the neutral to ground bond on the secondary side of the unit **shall** be referenced back to the common building grounding electrode system with no less than a 35 mm^2 csa (#2 AWG) or coarser, copper grounding conductor.

NOTE: Generators are often shipped from the manufacturer with a neutral to ground bond established within the generator unit. If the generator's ATS panel is not configured as a separately derived system, this bonding conductor must be removed.

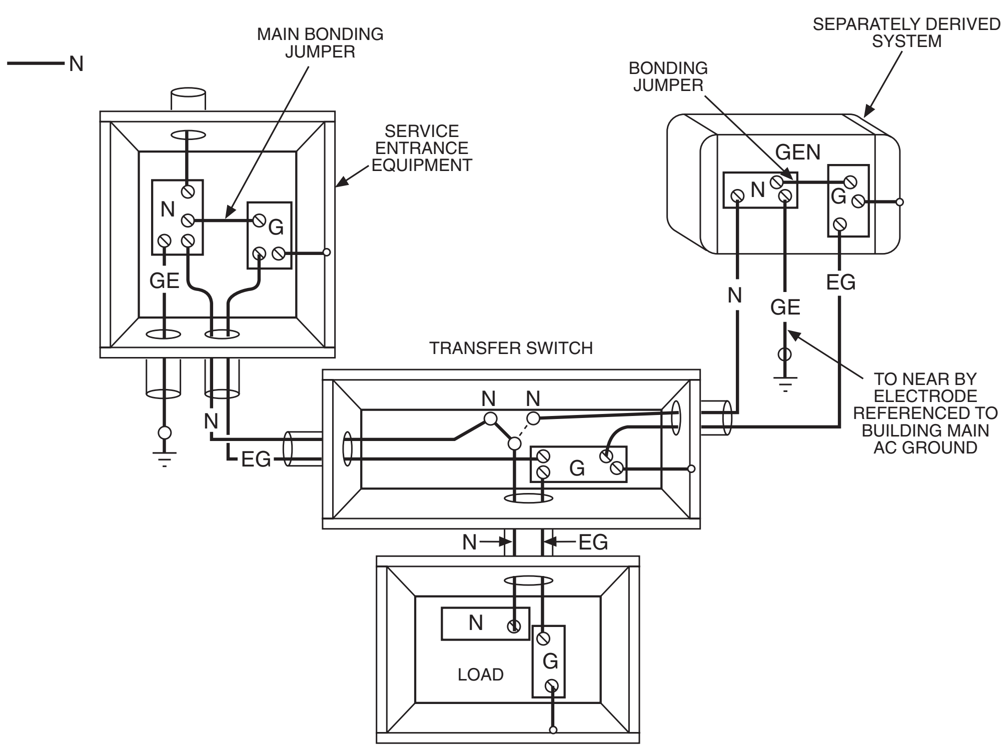


FIGURE 5-26 GENERATOR SYSTEM WITH SWITCHED NEUTRAL

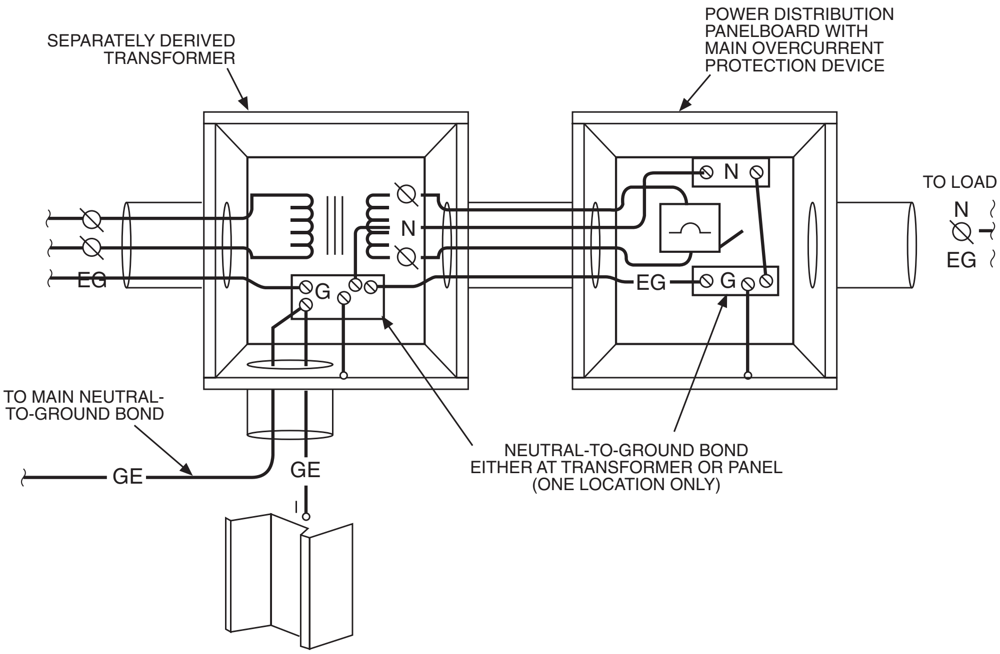


FIGURE 5-27 GROUNDING OF A DRY TYPE ISOLATION TRANSFORMER

5.5.1.2 DC POWER PLANT

The main DC power plant return bus **shall** be bonded to the facility single point grounding (earthing) system through a connection to the equipment room's single point ground. This single point ground should be the MGB, unless the MGB is located elsewhere in the building. In this case the grounding conductor can be effectively bonded to a properly installed SSGB. The DC power plant return bus **shall** be bonded to the single point ground with a grounding conductor no smaller than the largest conductor supplied by the DC power system, or no smaller than the grounding conductor for the SSGB and the grounding electrode conductor for the MGB. The DC power plant ground conductor **shall** be bonded to both bus bars with a compression-type two-hole UL 486A listed lug as described within this chapter. See Figure 5-28 for an example of this type of bonding configuration along with the required bonding of the power plant rack and battery rack frames (NFPA 70-2005, Articles 250.162, 250.164, and 250.166).

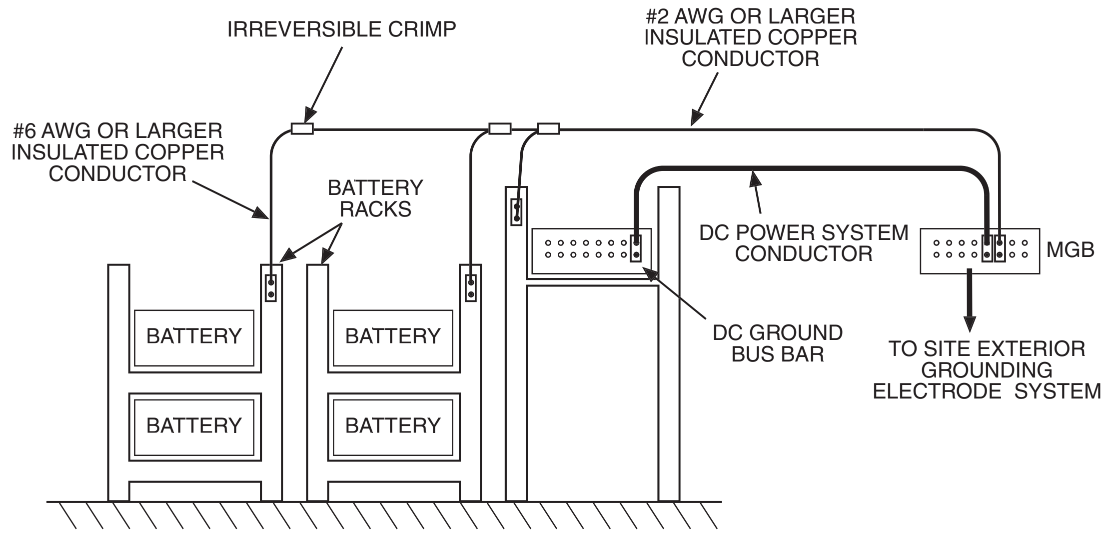


FIGURE 5-28 DC POWER PLANT AND FRAME GROUNDING

5.5.1.3 EQUIPMENT

The equipment grounding (earthing) conductor **shall** be attached to the equipment grounding terminal, chassis or frame utilizing methods described within this chapter. On equipment where a ground stud or connection point is provided by the manufacturer and this ground stud or connection point is sized and/or located so that a 16 mm^2 csa (#6 AWG) conductor cannot be reasonably attached, the 16 mm^2 csa (#6 AWG) equipment grounding conductor **shall** be attached to the equipment mounting screw or other suitable attachment point.

Where a terminal strip or other type connection point is an integral part of the equipment (PC board terminal, etc.) and this connection point must be connected to ground, a jumper sized per the manufacturer's instructions **shall** be installed between this point and the equipment grounding conductor. Manufacturer's installation instructions regarding grounding and bonding **shall** be followed in all instances unless the manufacturer specifies a grounding conductor smaller than 16 mm^2 csa (#6 AWG); in these cases a 16 mm^2 csa (#6 AWG) equipment grounding conductor **shall** be used. If the manufacturer has not provided specific grounding and bonding instructions for their equipment, the instructions contained within this paragraph **shall** prevail.

5.5.1.4 CABINETS AND RACKS

Conductor connections to racks and cabinets **shall** be made at the designated ground (earth) connection point or ground "pad." Connection to racks and cabinets without a designated connection point or ground pad **shall** be suitably made to the equipment mounting rail using bonding methods described within this chapter.

Racks or cabinets equipped with a RGB **shall** have an independent bonding jumper installed between the rack or cabinet grounding connection point and the RGB. Where its not practical to install a rack bonding jumper back to the RGB, the rack bonding jumper may be installed between the rack grounding connection point and the 35 mm^2 csa (#2 AWG) ground bus conductor or ground bus extension conductor using bonding methods described within this chapter. A stranded conductor may be more desirable due to the ease of installation and maintainability. All equipment within the rack or cabinet **shall** be bonded to the RGB with an equipment grounding conductor using bonding methods described within this chapter.

All metal non-current-carrying parts of the rack frame or cabinet enclosure that are to serve as grounding conductors, with or without the use of supplementary equipment grounding conductors, **shall** be effectively bonded where necessary to ensure electrical continuity and capacity to conduct any fault current likely to be imposed on them. To achieve effective bonding of the metal non-current-carrying parts, any non-conductive paint, enamel, or similar coating **shall** be removed at threads, contact points, and contact surfaces, or bonding must be connected using fittings designed to make such removal unnecessary (NFPA 70-2005, Article 250.96). If a bonding conductor is required, it **shall** be sized no smaller than 16 mm^2 csa (#6 AWG) and it **shall** be attached using bonding methods described within this chapter.

5.5.1.5 CABLE TRAYS

Bonding jumpers **shall** be installed at all cable tray splices and connection points unless the cable tray has labeling that identifies it as suitable for use as a grounding (earthing) conductor and it meets the requirements of NFPA 70-2005, Article 392.7(B). These type cable trays have bolted splices and the connection points use splined shoulder bolts which bite into the side rail of the cable tray to ensure a positive bond between sections. All bolts must be properly installed at each splice in the cable tray system per the manufacturer's instructions. Care must be taken to ensure a continuous electrical path. Bonding jumpers must be used where discontinuities such as expansion splice plates and hinged splice plates exist.

NOTE: Cable trays **shall not** be utilized as a ground bus conductor for equipment or ancillary support apparatus.

Bonding jumpers **shall** be installed on all metallic non-current-carrying portions of the cable tray system. A bonding jumper **shall** be installed between each cable tray section and between each piece of metallic non-current-carry support hardware to establish a effective current flow path back to the MGB. All bonding jumpers **shall** be as short and straight as possible. Where a bend is required in the bonding jumper, it **shall** adhere to the 203 mm (8 in.) minimum bending radius requirement. Cable trays with painted finishes or aluminum anodized finishes **shall** have the protective coating completely removed down to the bare metal at each bonding connection point, and the bonding connection point **shall** be treated with the appropriate type of conductive anti-oxidant compound before the bonding connection is established. See Figure 5-16 on page 5-23 for an example of this type of bonding configuration.

A cable tray system **shall** be effectively bonded back to the MGB with a grounding conductor no smaller than 16 mm^2 csa (#6 AWG). If the MGB is not located within the equipment room or area, the cable tray system **shall** be effectively bonded to the main SSGB within that room or area using bonding methods described herein. The grounding conductor connections between the cable tray and the MGB or SSGB **shall** be made using bonding methods described within this chapter.

When a cable tray system has been installed with a single section routing perpendicular to the MGB or SSGB, the cable tray section nearest to the bus bar **shall** have an equipment grounding conductor installed between one of the cable tray side rails and the MGB or SSGB. The grounding conductor **shall** be installed with the shortest and straightest routing possible. See Figure 5-29 for an example of this type of configuration.

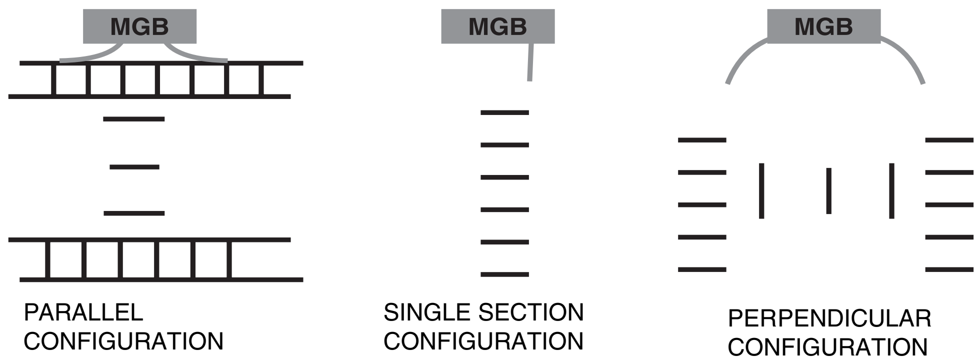


FIGURE 5-29 CABLE TRAY GROUNDING CONFIGURATIONS

When a cable tray system has been installed with a “U” shape section routing perpendicular to the MGB or SSGB, each cable tray section nearest to the bus bar **shall** have an equipment grounding conductor installed between the cable tray side rail and the MGB or SSGB. Each grounding conductor **shall** be installed with the shortest and straightest routing possible. See Figure 5-29 for an example of this type of configuration.

When a cable tray has been installed parallel to the MGB or SSGB, the cable tray section nearest to the bus bar **shall** have two equipment grounding conductors installed to provide a bidirectional flow path back to the MGB or SSGB. Each grounding conductor **shall** be installed with the shortest and straightest routing possible See Figure 5-29 for an example of this type of configuration.

5.5.1.6 ANCILLARY SUPPORT APPARATUS

All ancillary support apparatus within an equipment shelter, room or specific equipment area **shall** be bonded to the MGB. In areas other than where the MGB is installed, ancillary support apparatus **shall** be bonded to the SSGB, or to the internal perimeter ground (earth) bus conductor (IPGB), using an equipment grounding conductor and methods described within this chapter.

Manufacturers' installation instructions **shall** be followed when bonding ancillary support apparatus to the site grounding system. Connections **shall** be made to the terminal provided or some other suitable point on the apparatus.

Ancillary support apparatus includes but is not limited to:

- Storage cabinets
- Battery racks
- Metallic window frames, doors and door frames
- Metallic ceiling grids

- Metallic raised flooring systems
- HVAC grills, ducts, units, motors, motor controllers, control panels, junction and terminal boxes
- Panelboards
- Switchboards
- Automatic and manual transfer switches
- Transformers
- UPS units
- Metallic housing of AC power surge suppressor devices
- Primary surge suppressor ground terminals

The following **shall** also be bonded to the MGB, SSGB or IPGB system:

- All metallic support apparatus, including metallic conduits, within an equipment shelter, room, a generator or power distribution room, or specific equipment area and located within 2.4 m (8 ft.) vertically or 1.5 m (5 ft.) horizontally of ground or grounded metal objects (NFPA 70-2005, Article 250 (VI)).
- Rigid Metallic Conduit (RMC) and Electrical Metallic Tubing (EMT). **EXCEPTION:** when the conduits are effectively joined with threaded coupling, threadless coupling, or threadless compression connector, that terminate in bonded metallic enclosures, they may be considered adequately bonded and do not require additional bonding (ANSI T1.334-2002).
- If metallic conduit does not meet the above specifications, the electrical metallic conduits **shall** be bonded to the IPGB conductor at any point where they cross within 152 mm (6 in.) of the IPGB conductor.
- Metallic conduit run parallel to the IPGB conductor **shall** be bonded at the points where it enters to within 152 mm (6 in.) of the IPGB conductor and at the point where it transitions away from the IPGB conductor.
- All set-screw type connectors and couplings **shall** be bridged with a bonding jumper.
- Each metallic conduit may be connected to the IPGB conductor with a continuous equipment grounding conductor using removable saddle clamps or other clamps that specifically permit the use of a single continuous conductor for grounding multiple runs of conduit. If multiple conduits are grounded using a single conductor, the conductor **shall** be clamped to each conduit run such that removal of one clamp does not interrupt the path to ground for the other conduit runs. See Figure 5-30 on page 5-48.

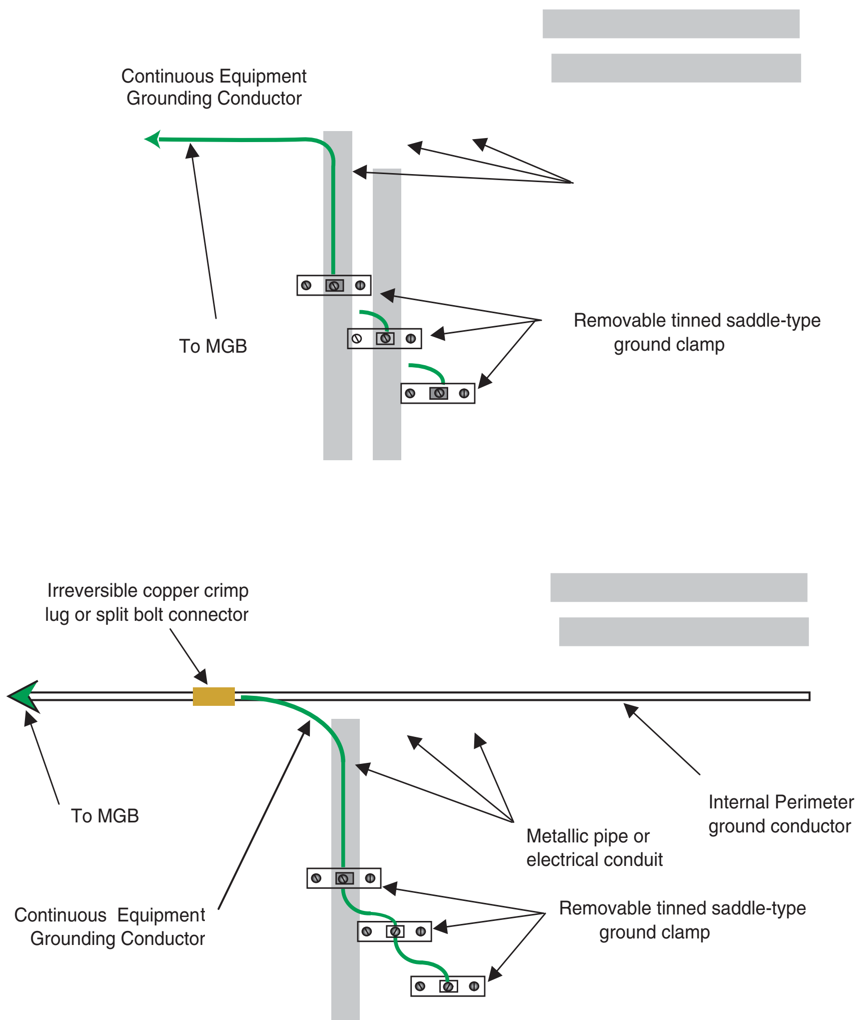


FIGURE 5-30 GROUNDING METHOD FOR METALLIC PIPE OR CONDUIT

5.5.1.7 METALLIC BUILDING STRUCTURE AND PIPING SYSTEMS

Metallic building structures and piping systems, steel roof trusses, exposed support beams and columns, drop ceiling grids, raised floor support structure, any metallic exposed building support structure and building frame when located within 2.4 m (8 ft.) vertically or 1.5 m (5 ft.) horizontally of the communications equipment, **shall** be bonded to the MGB, SSGB, or internal perimeter ground (earth) bus using one of the conductors and methods described within this chapter.
See Figure 5-21 on page 5-35.

No series or daisy chain connection arrangements **shall** be used. Each peripheral device **shall** be bonded to the MGB, SSGB, or perimeter ground bus using an individual equipment grounding conductor.

5.5.1.8 SURGE PROTECTION DEVICES (SPDS)

All surge protection devices and outside telecommunication cable metallic shields including, but not limited to, items listed below **shall** be effectively bonded back to the internal grounding (earthing) system with a 16 mm^2 csa (#6 AWG) or coarser equipment grounding conductor by using the following requirements and connection methods described within this chapter:

- Individual RF Surge Protection Devices
- Primary Surge Protection Devices
- Secondary Surge Protection Devices
- Telecommunication Cable Metallic Shields

5.5.1.8.1 RF SURGE PROTECTION DEVICES

RF transmission SPDs **shall** be bonded to the MGB within 610 mm (24 in.) of entry into the equipment shelter, equipment room or equipment area. A separate equipment grounding (earthing) conductor **shall** be used to bond each of these devices to the MGB or to a SSGB. RF transmission line SPDs may also be bonded directly to a SSGB, MGB, or the copper integrated entry panel with the proper securing hardware.

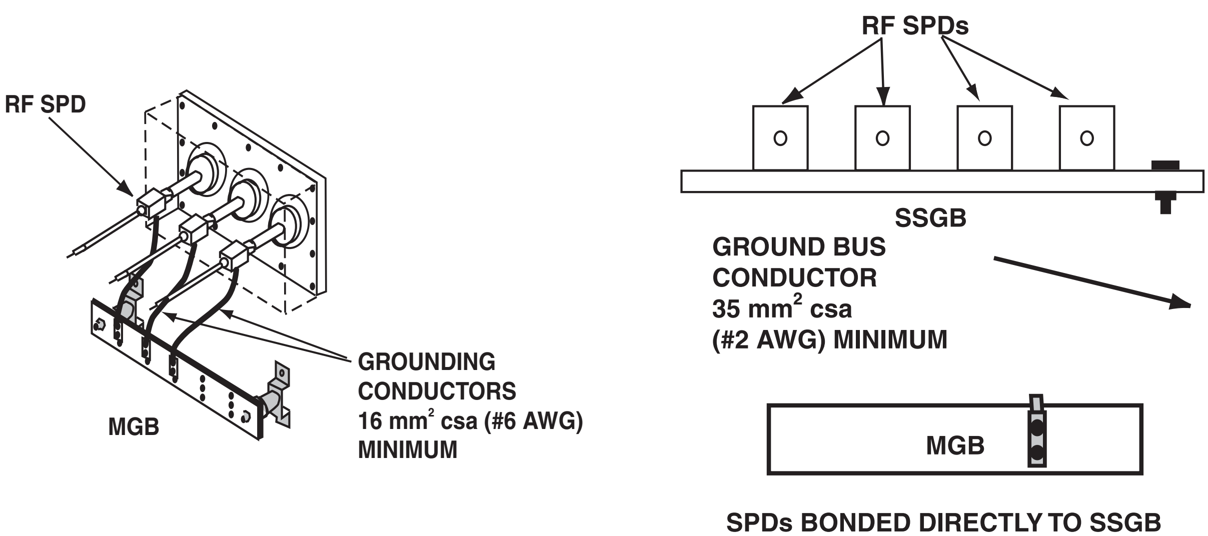
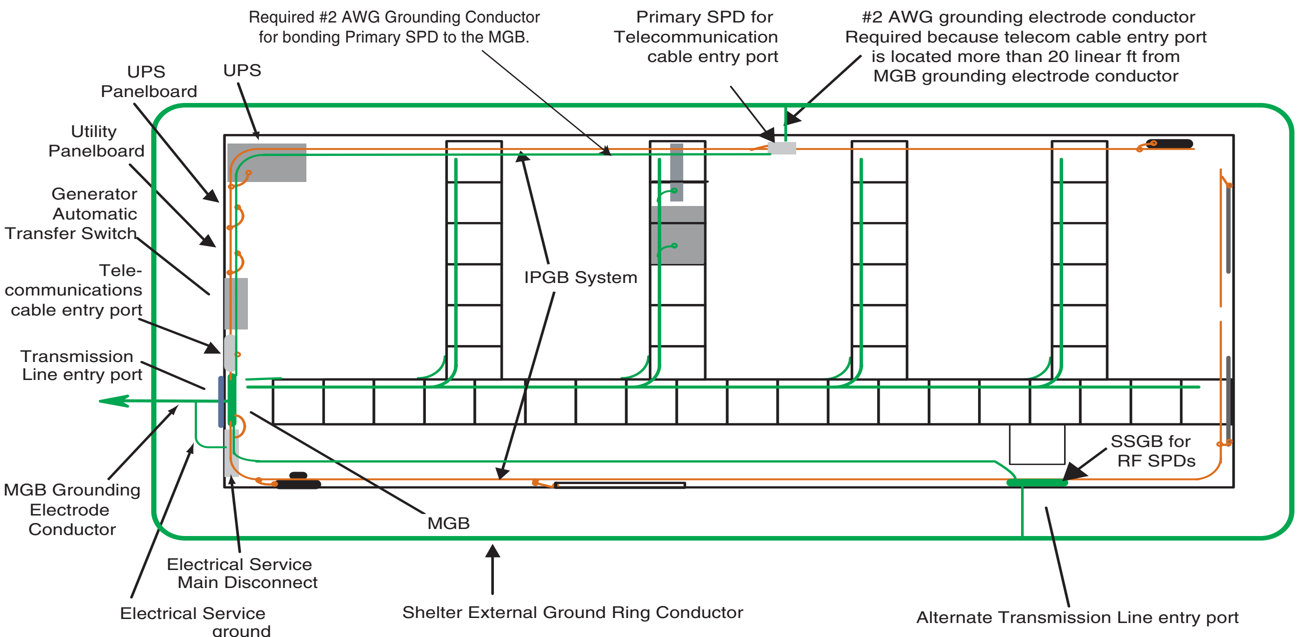


FIGURE 5-31 RF SPD BONDING TO SSGB WITH GROUNDING CONDUCTOR

If RF transmission lines enter the building at a point other than where the equipment room or area is located, there is no requirement for SPDs to be installed at that location. The shield of the RF transmission line **shall** be effectively bonded to the grounding electrode system at the point of entry into the building or as near as practicable thereto (NFPA-70-2005, Article 820.93).

Where a RF transmission line SPD is placed at the equipment shelter, equipment room or equipment area entry point and that entry point is greater than 6.1 linear metres (20 linear feet) away from the MGB's grounding electrode conductor connection to the grounding electrode system, a grounding electrode conductor **shall** properly installed between the SPD and the nearest accessible location of the common grounding electrode system as covered under NFPA 70-2005, Articles 810.21 and 820.100. The SPD **shall** also be effectively bonded back to the MGB by way of its SSGB or a ground bus conductor.



Note: This configuration is to be avoided whenever possible.

FIGURE 5-32 CABLE ENTRY GREATER THAN 6.1 LINEAR METRES (20 LINEAR FEET) FROM MGB GROUNDING ELECTRODE SYSTEM.

5.5.1.8.2 PRIMARY SURGE PROTECTION DEVICES

Primary SPDs for telephone circuits, data circuits, and control circuits **shall** have the ground (earth) terminal bonded to the MGB, SSGB or a dedicated ground bus conductor with an equipment grounding conductor using bonding methods described within this chapter. The grounding conductor for a single line primary SPD **shall** be 6 mm^2 csa (# 10 AWG) or coarser; the grounding conductor for multiple line primary SPDs **shall** be 16 mm^2 csa (# 6 AWG) or coarser. Where a primary SPD is placed at an entry point other than adjacent to the MGB and that point is greater than 6.1 linear metres (20 linear feet) away from the MGB's grounding electrode, a grounding electrode conductor **shall** properly installed between the primary SPD grounding terminal or its SSGB to the nearest accessible location on the common grounding electrode system as covered under NFPA 70-2005, Articles 800.100, 830.100. See Figure 5-32 for an example of this type of grounding configuration. In both cases, the conductors should maintain a minimum 305 mm (1 ft.) separation between cables of different cable groups, even when conductor is placed in rigid metallic conduit (ANSI-J-STD-607-A-2002).

5.5.1.8.3 SECONDARY SURGE PROTECTION DEVICES

All secondary SPDs **shall** be located as near as practical to the equipment they are protecting. A separate equipment grounding (earthing) conductor **shall** be used to bond each secondary SPD grounding conductor or ground terminal to the MGB, SSGB, RGB, or ground bus conductor that serves the associated equipment. The grounding conductor for a single line secondary SPD **shall** be 6 mm^2 csa (# 10 AWG) or coarser; the grounding conductor for multiple line secondary SPDs **shall** be 16 mm^2 csa (# 6 AWG) or coarser. When several secondary SPDs are installed at an equipment rack or cabinet, the SPDs should be placed at a central location within the rack or cabinet so they can be effectively bonded back to the equipment rack or cabinet RGB or back to a separately installed RGB. If a separate RGB is installed for the SPDs, it **shall** be effectively bonded back to the equipment ground bus system using bonding methods described in this chapter.

5.5.1.8.4 TELECOMMUNICATION CABLE METALLIC SHIELDS

Telecommunication cable metallic shields **shall** be bonded to the site's grounding electrode system as described herein. Where outside facility telecommunication cables are configured for a standard entrance, the metallic members of all incoming telecommunication cables, including paired-conductor and optical fiber cable, **shall** be grounded (earthed) to the MGB, either directly or through a SSGB at the facility's entrance point. Each metallic member **shall** be effectively bonded to the grounding point with a 16 mm^2 csa (#6 AWG) or coarser green-jacketed grounding conductor, or with a transmission line ground kit, using bonding methods described within this chapter. When the internal ground system is configured for functional categories 0 - 7 or PANI, the metallic members **shall** be bonded to reference point 0 or P. (See ANSI T1.313-2003 and paragraph 5.4.3 on page 5-36 for an explanation of PANI grounding.)

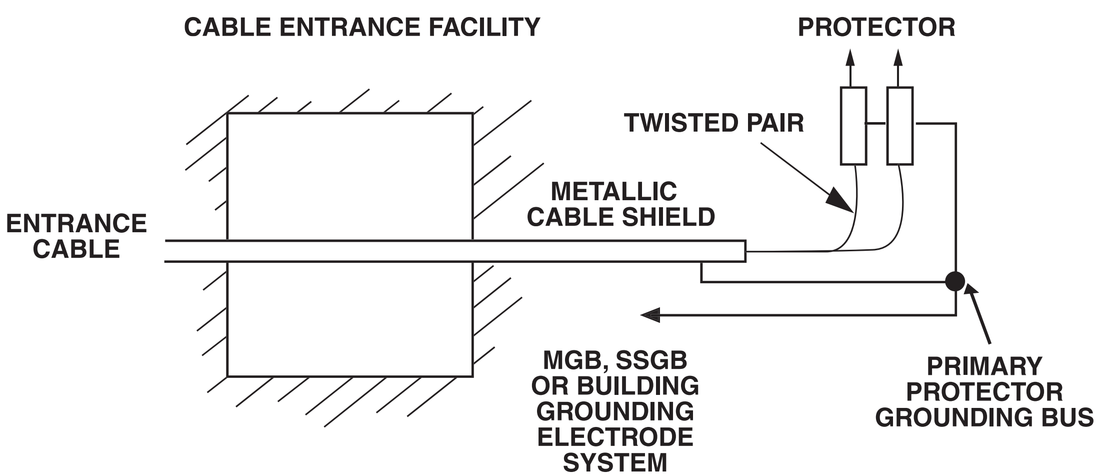


FIGURE 5-33 STANDARD TELECOMMUNICATIONS CABLE ENTRY LOCATION

When outside facility telecommunication cables are configured for an isolation entrance, the metallic member on the field side of the isolation gap **shall** be grounded back to the MGB, either directly or through a SSGB at the facility's entrance point. The bonding point for a PANI configured bus bar will be reference point P. The metallic member on the facility side of the isolation gap **shall** only be bonded at the primary SPD grounding terminal, which is grounded back to the SSGB or to the MGB at the PANI reference point P. In this type environment, the metallic members of all telecommunication cables entering the facility **shall** be isolated with a minimum 76 mm (3 in.) isolation gap. The isolation gap **shall** be sealed and insulated to prevent moisture penetration and flashovers during high voltage events. The grounding conductor for each side of the metallic member **shall** be a 16 mm^2 csa (#6 AWG) or coarser green-jacketed grounding conductor, and the grounding conductor **shall** be effectively bonded to the referenced grounding point using bonding methods described within this chapter (ANSI T1.313-2003).

NOTE: Isolation gaps, which interrupt the metallic members of all cables, may be installed in some locations as a protective measure against high lightning incidence. This method should be used with caution because it tends to compensate for electrical protection deficiencies in the outside plant (ANSI T1.313-2003). Consultation with a licensed professional engineer is recommended in these instances.

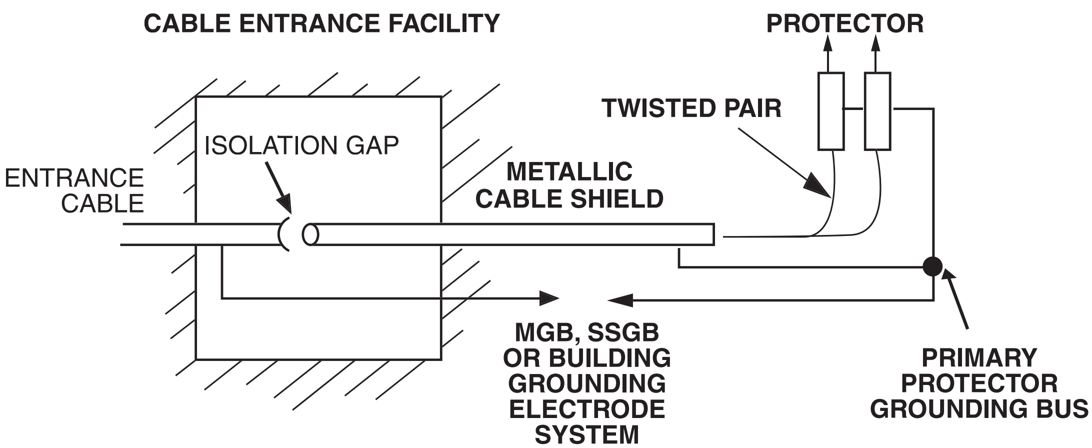


FIGURE 5-34 ISOLATION TYPE TELECOMMUNICATIONS CABLE ENTRY LOCATION

When the outside facility telecommunication cables are configured for an insulating entrance, the metallic members **shall** be bonded on each side of the insulating joint. The facility side of the insulating joint **shall** be bonded back to the MGB, either directly or through a SSGB at the facility's entrance point. The bonding point for a PANI configured bus bar will be reference point P. The grounding conductor for each metallic member on the facility side of the insulating joint **shall** be a 16 mm^2 csa (#6 AWG) or coarser, green-jacketed, grounding conductor and the grounding conductor **shall** be effectively bonded back the referenced grounding point using bonding methods described within this chapter. On the field side of the insulating joint, all metallic members and all associated metal are deliberately isolated from the site's common grounding electrode system. (See ANSI T1.313-2003 for additional information).

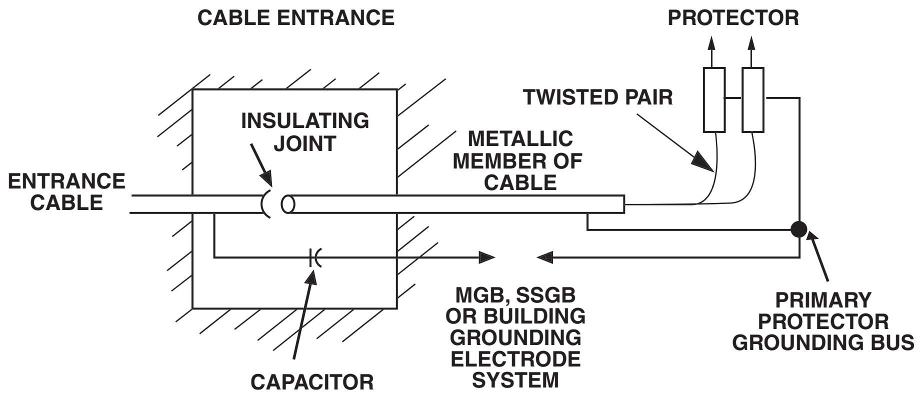


FIGURE 5-35 INSULATING TYPE TELECOMMUNICATIONS CABLE ENTRY LOCATION

Where internal telecommunication cables incorporate a shield or metallic member, the shield or metallic member **shall** be effectively bonded back to the closest MGB or SSGB with a 16 mm^2 csa (#6 AWG) or coarser, green jacketed, grounding conductor at the point where cables terminate or where they are broken out. Primary SPDs for interbuilding communication cables **shall** be bonded to the MGB or SSGB with a 16 mm^2 csa (#6 AWG) or coarser, green jacketed, grounding conductor as describe within the chapter. When secondary SPDs are installed at the equipment location, the SPD grounding conductor **shall** be effectively bonded to the closest MGB or SSGB as described within this chapter (ANSI-J-STD-607-A-2002).

5.5.1.8.5 METALLIC SHIELDS FOR INTERNALLY ROUTED SIGNAL CARRYING CABLES

The metallic shields of shielded RS-232 cables or similar type internally routed signal carrying cables **shall** be grounded (earthed) at one end only. A common shield ground wire **shall not** be used for input and output signals, for both high level and low level signals, for signal lines and power conductors, or for electronic signal lines and control lines. Where a signal ground (common return) conductor has been included within the cable, the signal ground wire **shall** only be bonded back to the shield at one end. The shield termination **shall** employ a minimum length pigtail between the shield and the shield pin of the connector. The size of the wire **shall** be as large as practical, but **shall not** be less than 1.5 mm^2 csa (#16 AWG) or the maximum wire size that will fit the connector pin. The unshielded length of signal cable **shall not** exceed 25 mm (1 in.) with a desired goal of not more than 13 mm (0.5 in.). See Figure 5-36 on page 5-53 for an example of the metallic shield grounding. See FAA-STD-019d-2002 for additional information.

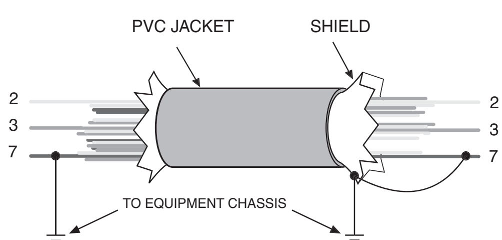


FIGURE 5-36 SIGNAL CABLE SHIELD BONDING

Cables consisting of multiple twisted pairs **shall** have the individual metallic shields isolated from each other. Cables with an overall metallic shield **shall** have the shield insulated. Signal carrying cable shields, individually and collectively, **shall** be isolated from overall shields of cable bundles and from electronic equipment cases, racks, cabinets, junction boxes, conduits, cable trays, and elements of the communications internal grounding system. Except for one interconnection as described above, individual shields **shall** be isolated from each other. This isolation **shall** be maintained in junction boxes, patch panels and distribution boxes throughout the cable run. Where a signal cable is interrupted such as a junction box, the shield **shall** be carried through. The length of unshielded conductors **shall not** exceed 25 mm (1 in.) and the length of the shield bonding conductor **shall** be the minimum required. (See FAA-STD-019d-2002 for additional information.)

Cables that have an overall shield over individually shielded pairs **shall** have the overall shield grounded at each end either directly through the connector or through an SPD. If a SPD is used it **shall** be bonded back to the equipment ground bus system as described within this chapter.

5.6 GROUNDING (EARTHING) FOR STAND-ALONE EQUIPMENT SHELTERS

Stand-alone equipment shelters are normally located next to a communication tower or placed on top of a large building to house the communications system equipment. Equipment located within the stand-alone equipment shelters is often subjected to disturbances from lightning. The information herein addresses the minimum electrical protection, grounding (earthing) and bonding requirements necessary to mitigate the disruptive and damaging effects of lightning on the equipment located within stand-alone shelters.

Not every facility will require the same level of electrical protection that is identified herein. Factors such as those related to telecommunication service reliability or local codes and standards, may dictate the need for electrical protection measures that exceed those described within this chapter.

Internal grounding systems within stand-alone equipment shelters may be configured in several different ways to protect the type of equipment that will be placed within them. It is of utmost importance to ensure that the internal grounding system is properly bonded to the tower or building's external grounding electrode system and that all grounding electrode systems at the location have been properly bonded together into a common grounding electrode system so that no major differences in ground potential exist at the site. See Chapter 4, “External Grounding (Earthing),” for complete information on external grounding.

5.6.1 INSTALLATION REQUIREMENTS FOR STAND-ALONE SHELTERS

The following are the grounding requirements for stand-alone equipment shelter installations:

- All towers, antenna structures, transmission lines, and other outside metallic items associated with the facility **shall** be effectively bonded back to a common grounding electrode system as described in Chapter 4, "External Grounding (Earthing)." (ANSI T1.334-2002, ANSI T1.313-2003, ANSI-J-STD-607-A-2002, NFPA 780-2004, FAA-STD-019d-2002)
- The internal grounding system **shall** have a MGB established within the facility that is effectively bonded to the common grounding electrode system as described in Master Ground (Earth) Bus Bar beginning on page 5-9. (ANSI T1.334-2002, ANSI T1.313-2003, FAA-STD-019d-2002, NFPA 70-2005)
- Where the main electrical service disconnect or the main electrical service panelboard is not installed on the same wall as the transmission line entry port, the MGB **shall** be located as close to the panelboard as practicable and it **shall** be installed to maintain clearances required by applicable electrical codes.
- The grounding electrode conductor for the electrical service neutral to ground bond **shall** be established in the main disconnect and bonded back to the shelter common external grounding electrode system as described within Chapter 4, "External Grounding (Earthing)," and Chapter 6, "Power Sources." The main disconnect grounding electrode conductor **shall** meet all installation requirements of applicable local and jurisdictional electrical codes (NFPA 70-2005, Article 250.64). Some acceptable examples of the grounding electrode conductors routing and bonding to the common external grounding system are provided in Figure 5-37.
- The electrical service alternating current equipment ground (ACEG) bus (when installed) or the main electrical service enclosure **shall** be bonded to the MGB with a 35 mm^2 csa (#2 AWG) green jacketed grounding conductor, using UL 486A listed two-hole compression type lug (ANSI T1.334-2002).
- All other communications system power sources **shall** be effectively bonded back to the MGB as described in paragraphs 5.5.1.1 on page 5-42 and 5.5.1.2 on page 5-43. (ANSI T1.334-2002, ANSI T1.313-2003, ANSI T1.333-2001, FAA-STD-019d-2002, NFPA 70-2005.)
- All outside facility telecommunications cables **shall** have their metallic shields properly bonded back to the internal grounding system as described in paragraph 5.5.1.8.4 on page 5-51 (ANSI T1.334-2002, ANSI T1.313-2003, ANSI-J-STD-607-A-2002, FAA-STD-019d-2002, NFPA 70-2005).
- All outside facility telecommunications cable primary SPDs at the facility entrance location **shall** be properly bonded to the internal grounding system as described in paragraph 5.5.1.8.2 on page 5-50 (ANSI T1.334-2002, ANSI T1.313-2003, ANSI-J-STD-607-A-2002, FAA-STD-019d-2002, NFPA 70-2005).
- All transmission lines and coaxial cable RF SPDs at the cable entry location **shall** be bonded to the internal grounding system as described in paragraph 5.5.1.8.1 on page 5-49 (ANSI T1.334-2002, FAA-STD-019d-2002, NFPA 70-2005).
- All externally routed power circuits, tower lighting conductors, video cables, telecommunications, alarm and control cables and RF transmission lines **shall** have SPDs installed as described in Chapter 7, "Surge Protective Devices," and the SPDs **shall** be effectively bonded back to the external or internal grounding system as described within this chapter (ANSI T1.334-2002; FAA-STD-019d-2002).

- All communications equipment within the facility **shall** be bonded back to the internal grounding system as described in paragraphs 5.5.1.3 and 5.5.1.4 on page 5-44 (ANSI T1.334-2002, ANSI T1.313-2003, ANSI-J-STD-607-A-2002, FAA-STD-019d-2002, NFPA 70-2005).
- All ancillary support apparatus and metallic non-current-carrying items within the facility **shall** be bonded back to the internal grounding system as described in paragraphs 5.4.2 on page 5-34 and 5.5.1.6 on page 5-46 (ANSI T1.334-2002, ANSI T1.313-2003, ANSI-J-STD-607-A-2002, FAA-STD-019d-2002, NFPA 70-2005).
- Where multiple pieces of ancillary support apparatus are bonded back to a perimeter ground bus system, the perimeter ground bus system **shall** meet the installation requirements of an IPGB system as described in paragraph 5.3.7 on page 5-28.
    - **Exception**: Although not preferred, an interior perimeter ground ring system (halo) installed per the requirements of ANSI T1.334-2002 is an acceptable ground bus system for bonding ancillary support apparatus and metallic non-current-carrying items only.

CAUTION

Electronic equipment shall not be bonded to the internal perimeter ground ring.

- If used, an interior perimeter ground ring system **shall** meet the following installation requirements:
    - All communications equipment within the facility **shall** be bonded to the internal grounding system as described within this chapter (ANSI T1.334-2002, ANSI T1.313-2003, ANSI-J-STD-607-A-2002, FAA-STD-019d-2002, NFPA 70-2005).
    - The interior perimeter ground ring **shall** be constructed of 35 mm^2 csa (#2 AWG) or coarser copper conductor.
    - The interior perimeter ground ring **shall** be located 305 mm (1 ft.) from the ceiling where practical.
    - The interior perimeter ground ring should be one continuous conductor bonded together with exothermic weld or irreversible compression connection.
    - The interior perimeter ground ring **shall** be supported at approximately 610 mm (2 ft.) intervals by standoff supports.
    - Minimum bending radius of the interior perimeter ground ring conductor **shall** be 305 mm (1 ft).
    - The interior perimeter ground ring conductor **shall** be bonded to the exterior ground ring with 35 mm^2 csa (#2 AWG) or coarser solid tinned copper conductors.
    - A grounding electrode conductor **shall** be placed at each corner of the shelter and bonded to the interior perimeter ground ring and exterior ground ring conductors with exothermically welded connections or irreversible compression connections.
    - If the length of the interior perimeter ground ring conductor exceeds 15 m (50 ft.) between the corner bonds, additional grounding electrode conductors to the exterior ground ring **shall** be placed at approximately equal intervals between the corner bonds.
    - The interior perimeter ground ring conductor **shall** be bonded to the MGB with a 35 mm^2 csa (#2 AWG) or coarser copper conductor.

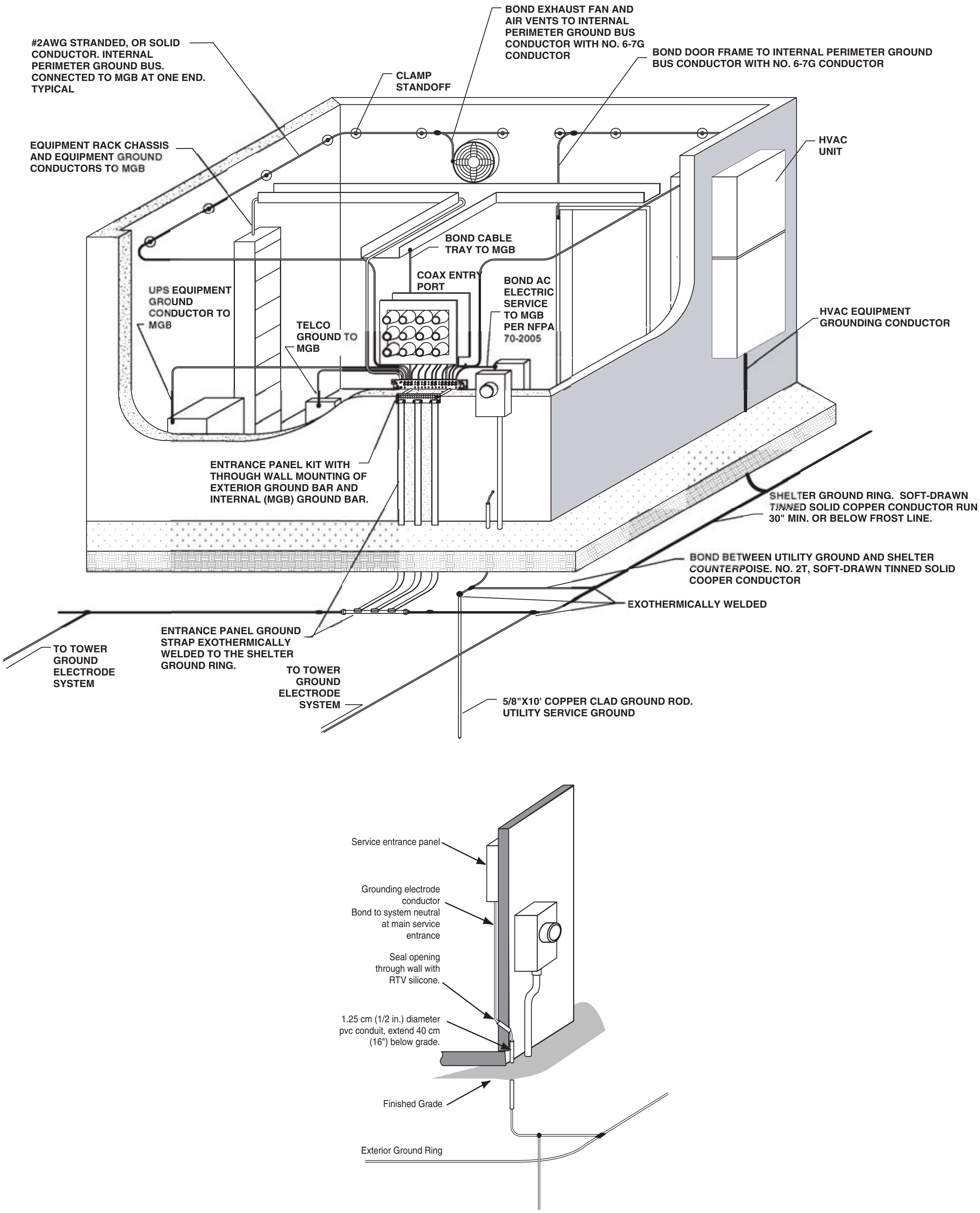


FIGURE 5-37 ROUTING OF ELECTRICAL GROUNDING ELECTRODE CONDUCTOR

5.7 GROUNDING (EARTHING) FOR SMALL, LARGE, AND MULTI-STORY BUILDINGS

Building infrastructure encompasses telecommunication spaces, pathway, cables, connecting hardware, and the telecommunication grounding (earthing) and bonding system (ANSI-J-STD-607-A-2002). The information herein specifies the requirements for establishing a uniform communication grounding system within a small, large or multistory building when an internal grounding system does not exist. For additional information, see ANSI-J-STD-607-A-2002.

5.7.1 ESTABLISHING A COMMUNICATION GROUNDING (EARTHING) SYSTEM

A MGB **shall** be properly installed as described herein and within “General Bonding Requirements” on page 5-31. The MGB serves as the dedicated extension of the building grounding (earthing) electrode system for the communication systems throughout the building. It also serves as a central attachment point for the communication bonding backbone conductor(s) and the equipment. There should only be a single MGB installed within the building. The following paragraphs are requirements of ANSI-J-STD-607-A-2002.

NOTE: Buildings or campuses with more than one electrical service entrance, each of which serves the communication system, require special design considerations that are beyond the scope of this document. Consultation with Motorola Engineering or with an engineering firm specializing in grounding system design is recommended in the instances.

The MGB **shall** be bonded back to the service equipment (power) ground with the shortest and straightest routing possible. The MGB grounding conductor should be routed to provide a direct downward flow path back to the building's grounding electrode system. If a bend is required in the MGB grounding conductor, minimum bending radius and angle **shall** be adhered to.

The ideal location for the MGB is in the telecommunications entrance facility, however the MGB should be located to minimize the length of the MGB grounding conductor back to the electrical service (power) ground where the electrical service neutral to ground bond has been established. When a panelboard is located within the same room as the MGB, the MGB **shall** be located as close to the panelboard as practicable and it **shall** be installed to maintain clearances required by applicable electrical codes. The MGB should also be located to provide the shortest and straightest routing for the telecommunications primary SPD grounding conductor. See Figure 5-38 for an example.

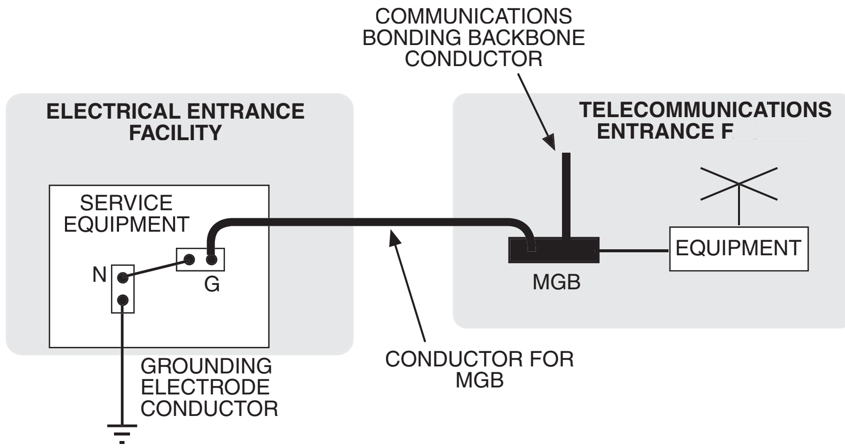


FIGURE 5-38 BONDING TO THE ELECTRICAL SERVICE (POWER) GROUND

At locations where communication bonding backbone conductors are used to interconnect multiple equipment rooms together, the communication bonding backbone conductors **shall** meet the installation requirements as specified in paragraph 5.3.6 on page 5-25. While the communication bonding backbone conductor will carry fault current under AC power ground fault conditions, it is not intended to serve as the only conductor providing a ground fault current return path.

SSGBs **shall** be installed as described herein and within paragraph 5.3.2 beginning on page 5-15. A main SSGB **shall** be placed in each communications equipment room or space as needed to keep equipment ground bus conductors or equipment grounding conductors as short as practicable. If a bend is required in the SSGB grounding conductor, minimum bending radius and angle **shall** be considered. When a panelboard for the communications equipment is located within the same room or space as the main SSGB, the SSGB **shall** be located as close to the panelboard as practicable and **shall** be installed to maintain clearances as required by applicable electrical codes.

5.7.2 SPECIFICATIONS FOR CONDUCTORS

All grounding (earthing) and bonding conductors **shall** be copper and may be insulated. When the conductors are insulated, they **shall** be listed for the space in which they are intended to be placed. See paragraph 5.3.4 beginning on page 5-20 for information on grounding conductor specifications.

All grounding and bonding conductors **shall** be sized according to their functions. Grounding conductor sizing specifications are located in the following sections:

- Ground bus conductors: paragraph 5.3.5.2 on page 5-25
- Communication bonding backbone conductors: paragraph 5.3.6.2 on page 5-26
- IPGB conductors: paragraph 5.3.7.2 on page 5-29
- Equipment grounding conductors: paragraph 5.3.8.2 on page 5-29
- Bonding jumpers: paragraph 5.3.9.2 on page 5-30

NOTE: Conductors installed within a plenum **shall** be compliant with NFPA 70-2005, Article 300.22 and cables installed within Information Technology rooms **shall** be compliant with NFPA 70-2005, Article 645. Ground conductors **shall** have an approved covering (insulation) or may be bare. When bare conductors are used they **shall** be solidly supported on suitable standoff insulators at intervals of no more than 610 mm (24 in.). These conductors **shall not** make contact with metallic surfaces or other conductors unless intended to be bonded to these surfaces or conductors.

NOTE: The interior water piping systems of the building and metallic cable shields **shall not** be used as communication bonding backbone conductors (ANSI-J-STD-607-A-2002).

In all cases, the main SSGB **shall** be bonded to the communication bonding backbone conductor or grounding equalizer conductor with a conductor the same size as the communication bonding backbone conductor. The MGB grounding conductor for the service equipment (power) ground **shall** be, at a minimum, the same size as the communication bonding backbone conductor (ANSI-J-STD-607-A-2002).

5.7.3 BONDING CONNECTIONS FOR THE MGB

The connection of the MGB grounding (earthing) conductor, the communication bonding backbone conductor(s) and ground bus conductors to the MGB **shall** utilize exothermic welding, listed compression two-hole lugs, or irreversible compression type connections. The connection of equipment grounding conductors that bond communications equipment to the MGB **shall** utilize exothermic welding, listed compression single-hole lugs, or other irreversible compression type connections. Two-hole lugs are preferred over single-hole lugs (ANSI-J-STD-607-A-2002).

NOTE: All grounding and bonding connectors **shall** be listed for the application by a nationally recognized testing laboratory (ANSI-J-STD-607-A-2002).

The MGB grounding conductor **shall** be bonded to the building's common grounding electrode system as described in paragraph 5.3.1.3 on page 5-12.

5.7.4 BONDING CONNECTIONS FOR THE SSGB

The grounding (earthing) conductor between the main SSGB and the communication bonding backbone conductor **shall** be continuous and routed in the shortest possible straight line path back towards the MGB. If a bend is required in the SSGB grounding conductor, minimum bending radius and angle **shall** be adhered to. The grounding conductor **shall** be connected to the SSGB with exothermic welding, compression two hole lug, or an irreversible compression type connector. The SSGB grounding conductor **shall** be connected to the communication bonding backbone conductor or to the grounding equalizer conductor with exothermic welding or irreversible compression-type connection. The connection of equipment grounding conductors for bonding communications equipment to the SSGB **shall** utilize exothermic welding, listed compression single-hole lugs, or other irreversible compression type connections. Two-hole lugs are preferred over single hole-lugs (ANSI-J-STD-607-A-2002)

NOTE: All grounding and bonding connectors **shall** be listed for the application by a nationally recognized testing laboratory (ANSI-J-STD-607-A-2002).

When a grounding equalizer conductor is bonded to a main SSGB, the grounding equalizer conductor **shall** be connected to the SSGB using exothermic welding, compression two-hole lugs, or irreversible compression type connections.

5.7.5 ITEMS TO BE BONDED TO THE INTERNAL GROUND (EARTH) SYSTEM

See ANSI-J-STD-607-A-2002 for additional information. When a electrical power panelboard is located in the same room or space as the MGB or SSGB, that panelboard's alternating current equipment ground (earth) (ACEG) bus or the panelboard enclosure **shall** be effectively bonded to the MGB or the SSGB with a 16 mm^2 csa (#6 AWG) or coarser grounding conductor. Where a panelboard for the communications equipment is not located in the same room or space as the SSGB, consideration should be given to bonding panelboard ACEG bus or the panelboard enclosure back to the SSGB with a properly sized grounding conductor. In all cases the grounding conductor should be sized according to its length in accordance with the requirements in Table 5-5 on page 5-29.

All metallic raceways or cable trays for telecommunication cabling that is located within the same room or space as the MGB or a main SSGB **shall** be effectively bonded back to the MGB or the SSGB with a 16 mm^2 csa (#6 AWG) or coarser, grounding conductor as described in paragraph 5.5.1.5 on page 5-45.

When structural building steel is readily accessible within the room of a MGB or main SSGB, the MGB and/or SSGB **shall** be effectively bonded to the vertical steel frame with a 16 mm^2 csa (#6 AWG) or coarser, grounding conductor by following bonding methods in paragraphs 5.4.2 on page 5-34 and 5.4.3 on page 5-36. If the structural steel frame is external to the room or space of the MGB or SSGB and readily accessible, the steel frame should be bonded back to the MGB or SSGB with a 16 mm^2 csa (#6 AWG) or coarser, grounding conductor as described above. The MGB or SSGB grounding conductor **shall** be bonded to the vertical steel column, routed downward toward the earth's surface. When practicable because of shorter conductor runs and where horizontal steel members of the building frame are permanently and electrically bonded to the vertical column members, the SSGBs may be bonded to the horizontal members. The grounding conductor should be sized according to its length as shown in Table 5-5 on page 5-29, and if a bend is required in the grounding conductor, minimum bending radius and angle **shall** be adhered to.

The telecommunications primary SPD grounding conductor **shall** be connected to the MGB using the shortest and straightest routing path practical. A minimum separation distance of 305 mm (1ft) **shall** be maintained between other cable groups even if the conductor is routed inside a metallic conduit. See paragraph 5.5.1.8.2 on page 5-50 for additional information.

At the location where telecommunications cabling enters the building, the metallic shields **shall** be bonded to the building's grounding system by one of the methods described in paragraph 5.5.1.8.4 beginning on page 5-51. Where internal backbone telecommunication cables (telephone system cables) incorporate a shield or metallic member, the shield or metallic member **shall** be effectively bonded to the closest MGB or main SSGB with a 16 mm^2 csa (#6 AWG) or coarser green jacketed grounding conductor at the point where cables terminate or where they are broken out. Primary SPDs for inter-building communication cables **shall** be bonded to the MGB or SSGB with a 16 mm^2 csa (#6 AWG) or coarser, green jacketed grounding conductor as described in paragraph 5.5.1.8.2 on page 5-50. When secondary SPDs are installed at the equipment location, the SPD grounding conductor **shall** be effectively bonded to the closest MGB or SSGB as described in paragraph 5.5.1.8.3 on page 5-51.

Where external antenna cables enter the building, that point of entry **shall** be treated as a cable entrance location (ANSI-J-STD-607-A-2002). The cable entrance location **shall** have an accessible bonding location to the building's common grounding electrode system (e.g., an external ground bus bar or structural building steel). The outer metallic shields of each transmission line and other communications cables **shall** be bonded to the building's common grounding electrode system (NFPA 70-2005, Articles 770.93, 800.100, 810.20, 820.93, 820.100, and 830.100). See “External Ground Bus Bar” on page 4-30 for additional information.

5.8 GROUNDING (EARTHING) FOR DISPATCH CENTERS AND NETWORK OPERATOR POSITIONS

Dispatch centers co-located with communication towers require special protection considerations due to the critical nature of their operation and due to the inherent risk to personnel from lightning events. For optimum protection of a dispatch center, the following **shall** be considered:

- Site design recommendations given in “Design Considerations to Help Reduce Effects of Lightning” on page 2-19.
- External grounding (earthing) and bonding as defined in Chapter 4, “External Grounding (Earthing).”
- Transient voltage surge suppression (TVSS) as defined in “Telephone/Control/Data Network Circuit SPDs” on page 7-34.
- Electrostatic discharge (ESD) precautions as defined in Appendix C.

This section provides electrical protection measures that are intended to help protect network operators, and to help ensure reliable equipment operation during periods of lightning activity or surges from AC power lines and power switching operations.

5.8.1 GROUNDING (EARTHING) AND PROTECTION OF INCOMING POWER AND TELECOMMUNICATION CABLES

To minimize the effects of lightning and AC power surges at the facility, a common internal grounding (earthing) system **shall** be installed as described in "Grounding (Earthing) for Small, Large, and Multi-Story Buildings" on page 5-58. Applicable surge protection devices **shall** be installed on all incoming power lines and telecommunication cables as described in Chapter 7, "Surge Protective Devices," and the surge protection devices **shall** be effectively bonded back to the common internal grounding system as described in this chapter. All outside facility telecommunication cables entering the building and their surge protection devices **shall** be effectively bonded back to the internal grounding electrode system as described within this chapter.

Any co-located Lightning Protection System (LPS), communication tower, or outside mounted antenna **shall** also be effectively bonded back to the site's common grounding electrode system as described in Chapter 4, "External Grounding (Earthing)."

5.8.2 GROUNDING (EARTHING) OF EQUIPMENT ROOMS LOCATED WITHIN THE DISPATCH CENTER

All communications system equipment rooms located in the same building and fed by the same electrical service **shall** have a single point grounding (earthing) location established within the room or space. This location can be the communications system MGB, an SSGB, or a properly sized ground bus conductor. In all cases, the single point grounding location **shall** be effectively bonded back to the communications system common internal grounding system as described within this chapter.

NOTE: Buildings or campuses with more than one electrical service entrance, each of which serves the communication system, require special design considerations that are beyond the scope of this manual. Consultation with Motorola Engineering or with an engineering firm specializing in grounding system design is recommended in these instances.

All interconnect communications system equipment and ancillary support equipment located within the communication equipment room **shall** be effectively bonded back to the single point grounding location in accordance with the requirements within paragraphs 5.5.1.3 and 5.5.1.4 on page 5-44, and 5.5.1.6 on page 5-46.

All voltage limiting SPDs located within the communication equipment room **shall** be effectively bonded to the single point grounding location in accordance with paragraph 5.5.1.8 and the associated paragraphs beginning on page 5-49.

5.8.3 GROUNDING (EARTHING) AND PROTECTION OF NETWORK OPERATOR POSITIONS AND WORK AREAS

When a network operator location is not properly protected, electrical disturbances may appear at the work position that could possibly harm the operator and/or damage the equipment. These electrical disturbances can arise from sources external or internal to the building such as lightning, ac power disturbances, or electrostatic discharge (ESD). To adequately protect the operator and the equipment at the position, an adequate grounding (earthing) system and the required surge suppression devices **shall** be installed as described within this chapter.

Equipotential bonding at the network operator position is essential in providing personnel safety and equipment reliability. A network operator position often contains a headset, headset interface equipment, and other electronic equipment such as consoles, computers, video displays, small emergency radios, and furniture. Work positions are frequently arranged in clusters within a dispatch room and the operator equipment is interconnected with other communication system equipment located throughout the building. In these instances, it is not only important to establish equipotential bonding at the operator position, it is also necessary to establish it between any adjacent operator positions. The ground potential **shall** also be equalized between any interconnected communication systems within the building that are fed by the same electrical service.

5.8.3.1 EQUIPOTENTIAL GROUNDING (EARTHING) OF THE NETWORK OPERATOR POSITION

All network operator equipment, including but not limited to the items listed below, **shall** be effectively bonded back to the communication systems MGB using methods described within this chapter. See ANSI T1.321-R2000 for additional information.

- Equipment supplied with a ground (earth) connection point
- Mounting rails or support brackets intended for mounting equipment on or within the furniture
- Metallic parts of network operator furniture
- Telecommunication cable shields
- Data cable shields
- Voltage limiting secondary surge protection devices

A SSGB **shall** be installed at the network operator position area. If several network operator positions are arranged in a cluster, a single SSGB may be shared at each cluster, provided equipment grounding conductor length restriction can be met.

Each network operator position SSGB **shall** be effectively bonded back to the MGB or a common collection point SSGB within the area or space, using an adequately sized ground bus conductor.

The ground bus conductor **shall** be as short and straight as practical and **shall** be bonded to the SSGBs using the connection methods described in paragraph 5.4.4 on page 5-38. See Table 5-3 and Table 5-4 on page 5-27 for ground bus conductor sizing requirements. When used, the main collection point SSGB for the dispatch room **shall** be bonded back to the communication bonding backbone conductor as described within this chapter.

All bonding connections at the network operator position or cluster of positions **shall** be terminated on the SSGB. The SSGB **shall** be located so that the equipment grounding conductor length is as short as possible. In order to keep inductance low, all equipment grounding conductors **shall** be kept as short and straight as practicable. Equipment grounding conductors **shall not** be coiled or looped.

All metallic equipment enclosures, frames, and chassis, as well as the operator position furniture (other than chairs) **shall** be effectively bonded to the SSGB using conductors as follows:

- 16 mm^2 csa (#6 AWG) insulated copper conductor for lengths not exceeding 3.9 m (13 ft.).
- 6 mm^2 csa (#10 AWG) insulated copper conductor for lengths not exceeding 3 m (10 ft.).
- If a longer length is required, the equipment grounding conductor should be sized according to Table 5-5 on page 5-29.

Equipment mounting rails or support brackets intended for mounting equipment within the furniture **shall** be bonded to the ground system by attaching a 16 mm^2 csa (#6 AWG) insulated copper conductor to a single mounting rail or bracket. In instances where an equipment chassis or housing is installed between mounting brackets or rails and the equipment chassis or housing has a designated ground connection point, an additional equipment grounding conductor **shall** be attached to the designated grounding connection point of the equipment.

Equipotential bonding at a network operator position should be integrated into the position equipment to the greatest extent possible. This will largely reduce the need to place equipment grounding conductors. All telecommunication cable shields, data cable shields, and the equipment or furniture AC equipment ground (ACEG) **shall** be bonded together at the position SSGB or within the equipment.

Outer shields of telecommunication cables serving the network operator position or cluster of positions (to or from a different location) **shall** be bonded directly to the SSGB or by using conductors as follows:

- 16 mm^2 csa (#6 AWG) insulated copper conductor for lengths not exceeding 3.9 m (13 ft.).
- 6 mm^2 csa (#10 AWG) insulated copper conductor for lengths not exceeding 1.8 m (6 ft.).

The outer shield ground is provided automatically when the cable connector contains a shield-to-chassis connection.

When AC power is present at a network operator position, the AC power receptacle housing or ACEG **shall** bond to the SSGB using a conductor as follows:

- 6 mm^2 csa (#10 AWG) insulated copper conductor for lengths not exceeding 914 mm (3 ft.)
- 16 mm^2 csa (#6 AWG) insulated copper conductor for length exceeding 914 mm (3 ft.)

The conduit or raceway serving the receptacle box **shall not** be relied upon as the sole ACEG at the position. A separate, insulated ACEG conductor **shall** be run with the branch circuit supply conductors, and **shall** be properly bonded to the metallic receptacle box, conduit or armored cable per the requirements of NFPA 70-2005. The ACEG conductors of AC branch circuits serving network operator equipment positions **shall not** be electrically isolated from the building grounding and bonding network in any way. Due to the required bonding of the ACEG conductor to the SSGB, isolated ground receptacles **shall not** be used (ANSI T1.321-R2000).

Exposed metallic objects located within 2.4 m (8 ft.) vertically or 1.5 m (5 ft.) horizontally from the operator position (such as building steel, ventilation ducts, and the nearest raised flooring system support pedestal) **shall** be effectively bonded to the operator position SSGB with a minimum 16 mm^2 csa (#6 AWG) copper conductor of the shortest and straightest length possible.

Surge protection devices should be present on all AC power, telephone and data communication cables at every network operator position or cluster to help minimize voltages between communication conductors and conductive surfaces (see Chapter 7, "Surge Protective Devices"). When SPDs are present, they **shall** be bonded to the SSGB using conductors as follows:

- 6 mm^2 csa (#10 AWG) insulated copper conductor for lengths not exceeding 914 mm (3 ft.).
- 16 mm^2 csa (#6 AWG) insulated copper conductor for lengths not exceeding 3.9 m (13 ft.).

The grounding conductors **shall** be run using the shortest, most direct route as practicable.
See Figure 5-39 for a high level overview of the required bonding.

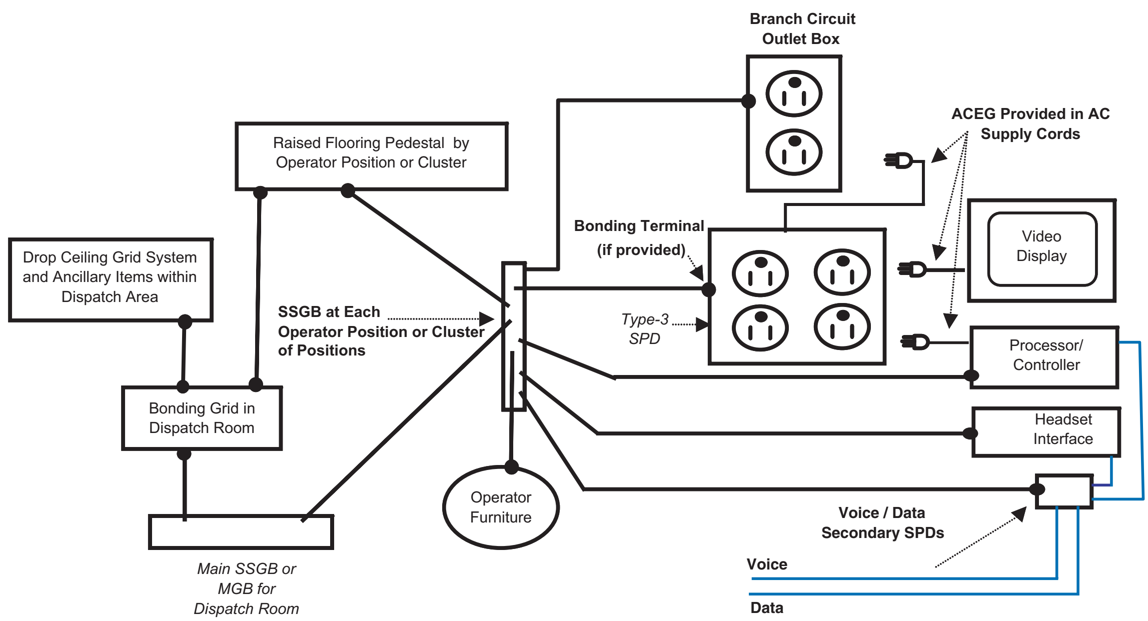


FIGURE 5-39 EXAMPLE OF NETWORK OPERATOR POSITION GROUNDING

5.8.3.2 INTERPOSITION BONDING FOR MULTI-CLUSTER NETWORK OPERATOR POSITIONS

When a dispatch room is configured with multiple network operator position clusters, consideration should be given to establishing a bonding grid that interconnects all network operator position SSGBs and equalizes potentials among the clusters. This bonding grid will be of value if an operator of one cluster, while still connected to his or her own position, approaches a position in an adjacent neighboring cluster. When a bonding grid is installed it **shall** meet the requirements of this paragraph. See Figure 5-40 and Figure 5-41 on page 5-67 for examples.

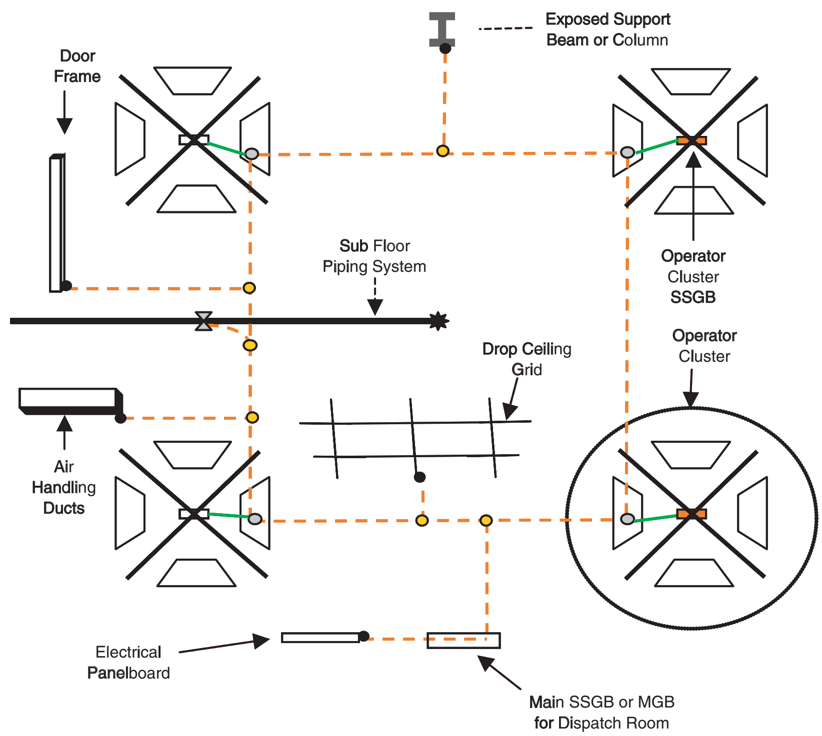


FIGURE 5-40 RAISED FLOORING GROUNDING GRID, SHOWING BONDING OF ANCILLARY SUPPORT APPARATUS TO THE BONDING GRID

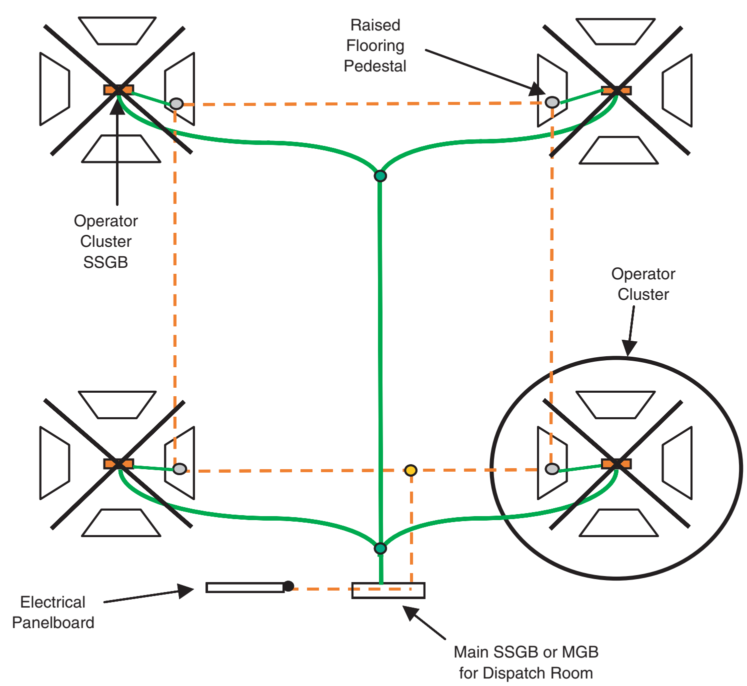


FIGURE 5-41 RAISED FLOOR GROUNDING GRID AND NETWORK OPERATOR EQUIPMENT GROUND BUS SYSTEM

If a bonding grid is present, it should be used to bond the raised flooring system supports at each grid node location and suspended ceiling grids, in at least four places, preferably at the corners of the dispatch area, using bonding methods described in this chapter. Other items such as electrical panelboards, metallic water fountains, metallic plumbing, metallic ventilation ducts and other metallic ancillary support items **shall** be bonded back to the nearest bonding grid conductor with a minimum 16 mm^2 csa (#6 AWG) copper conductor of the shortest length possible.

The bonding grid should be established within the same space used to run electrical power and communication cables to the operator positions. This space can be below a raised flooring system that supports the operator positions, the space immediately below the structural floor supporting the operator positions, or the space above a suspended ceiling grid system when a raised flooring system has not been installed (ANSI T1.321-R2000).

The bonding grid **shall** be made from 16 mm^2 csa (#6 AWG) or coarser stranded copper conductor that may be jacketed as allowed by the space where it will be installed. The grid node connections **shall** be made using irreversible compression-type connections that are listed for the purpose. Each grid node connection should be positioned vertically below or above (ceiling area) each cluster SSGB. The grid nodes may be established with horizontal offsets of 1.5 m (5 ft.) or less from a cluster. Each cluster SSGB **shall** be connected to its associated grid node with a minimum 16 mm^2 csa (#6 AWG) copper conductor of the shortest and straightest length possible. The SSGB grounding conductor **shall** be no greater than 3.9 m (13 ft.) in length. If greater lengths are needed, the SSGB grounding conductors and the bonding grid conductor **shall** be sized up to 35 mm^2 csa (#2 AWG).

The bonding grid **shall** be effectively bonded to the dispatch room main collection point SSGB or MGB with a copper bonding conductor of the same size as the bonding grid conductor. This bonding conductor **shall** be bonded to the nearest bonding grid conductor with an exothermically welded or an irreversible compression-type connection. The conductor **shall** be bonded to the SSGB or MGB with exothermic welding, irreversible compression two-hole lug, or other irreversible compression means.

5.9 GROUNDING (EARTHING) FOR INTEGRATED COMMUNICATION SITES

For communications sites located on the rooftop or within a high-rise building whose primary purpose is something other than a communications site, connection of the communications internal grounding (earthing) system **shall** be made to the building's common grounding electrode system as described herein and within this chapter.

The information within this section specifies the requirements for establishing an integrated communications site grounding system on or within a high-rise building where an internal grounding system does not exist. When communications equipment is located on or within a building with an established grounding system, the communications equipment **shall** be effectively bonded back the common bonding network (CNB) for the building. See ANSI T1-313-2003 and ANSI T1.333-2001 for additional information on bonding to the building CBN.

At high-rise sites, connection to effectively grounded structural building steel is the preferred connection location for the equipment room MGB. In poured concrete buildings where structural building steel may not be an option, effectively grounded and accessible rebar may be considered for use as a connection point. If these options are not available, use the other methods recommended within this section.

An adequately sized MGB **shall** be installed within the equipment area by following the requirements in paragraphs 5.3.1 on page 5-9, 5.3.1.1 on page 5-9, 5.3.1.2 on page 5-11, and 5.3.1.3 on page 5-12. The MGB **shall** be effectively bonded to the nearest accessible location on the building's common grounding electrode system. Bonding of the MGB to the building's common grounding electrode **shall** be made using one or more of the following recommendations below:

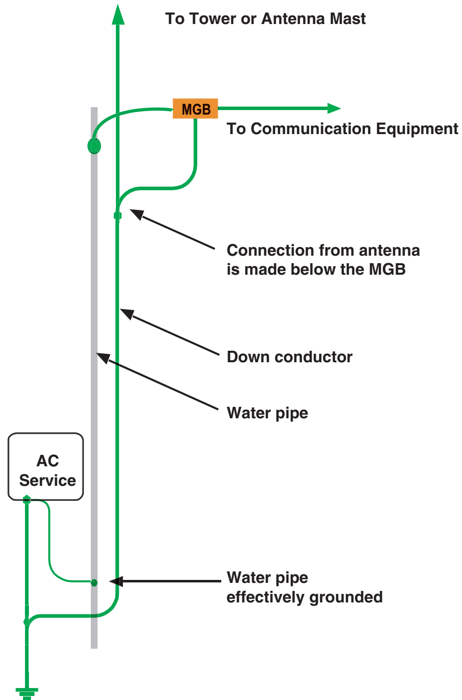
IMPORTANT: At sites, such as high-rise buildings, where it is difficult to achieve an effective grounding electrode system, the need for single-point grounding and transient voltage surge suppression (TVSS) on all input/outputs is of paramount importance.

- Bonding to an existing building grounding backbone-type system.
- Installation of a bonding backbone conductor(s) as described in “Communication Bonding Backbone Conductor and Grounding (Earthing) Equalizer Conductors” on page 5-25.
    - Grounding conductor **shall** be run in as straight a line as is practical (NFPA 70-2005, Article 810.21(E) and ANSI T1.313-2003) and **shall** be run in a downward direction.
    - Minimum bend radius of grounding conductors **shall** be 203 mm (8 in.), and the included angle **shall not** exceed 90 degrees as shown in Figure 5-13 on page 5-19 (NFPA 780-2004, Section 4.9.5 and ANSI T1.313-2003).
    - Grounding conductors **shall** be permitted to be run either outside or inside the building or structure (NFPA 70-2005, Article 810.21(G)).
    - Grounding conductors **shall** be protected where exposed to physical damage (NFPA 70-2005, articles 250.64, 800.100, 810.20, 820.100; and NFPA 780-2004, section 4.9.11).
    - Grounding conductors **shall** be securely fastened at intervals not exceeding 914 mm (3 ft.) (ANSI T1.334-2002, section 8.3 and NFPA 780-2004, Section 4.10.)
    - Grounding conductors exposed to physical damage **shall** be protected for a minimum distance of 1.8 m (6 ft.) above grade level (NFPA 780-2004, section 4.9.11.2). Such areas may include, but are not limited to, runways, driveways, school playgrounds, cattle yards, public walks (NFPA 780-2004, section 4.9.11).
- Bonding to effectively grounded metallic piping systems under the advice of the building engineer.

NOTE: Gas piping systems **shall not** be used as part of a grounding electrode system (NFPA 70-2005, Article 250.52(7)(B)), but **shall** be bonded upstream from the equipment shut-off value to the grounding electrode system as required by NFPA 70-2005, article 250.104 and NFPA 780-2004, section 4.14.1.3.

NOTE: In situations where metal piping systems (other than gas piping) may be required for use as part of a grounding electrode system, electrical continuity **shall** first be verified. See NFPA 70-2005, Article 250.68(B) for more details.

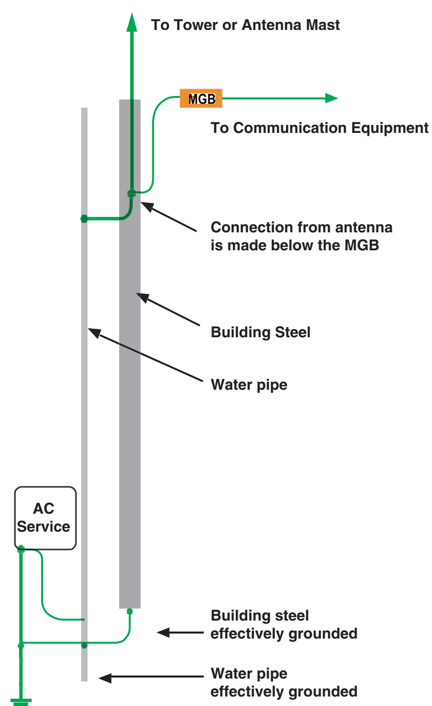
Figure 5-42, Figure 5-43, and Figure 5-44 show grounding options for integrated sites.



NOTES:

1. 35 mm^2 csa (#2 AWG) conductor for runs of 10 m (33 ft.) or less.
2. 95 mm^2 csa (#3/0 AWG) conductor for runs longer than 26 m (84 ft.)
3. See Table 5-3 on page 5-27 for other cable lengths and conductor sizing requirements.

FIGURE 5-42 SITE ON DIFFERENT FLOOR THAN AC SERVICE FEED, BUILDING STEEL NOT AVAILABLE



NOTES:

1. 35 mm^2 csa (#2 AWG) conductor for runs of 10 m (33 ft.) or less
2. 95 mm^2 csa (#3/0 AWG) conductor for runs longer than 26 m (84 ft.)
3. See Table 5-3 on page 5-27 for other cable lengths and conductor sizing requirements.

FIGURE 5-43 SITE ON DIFFERENT FLOOR THAN AC SERVICE FEED, BUILDING STEEL AVAILABLE

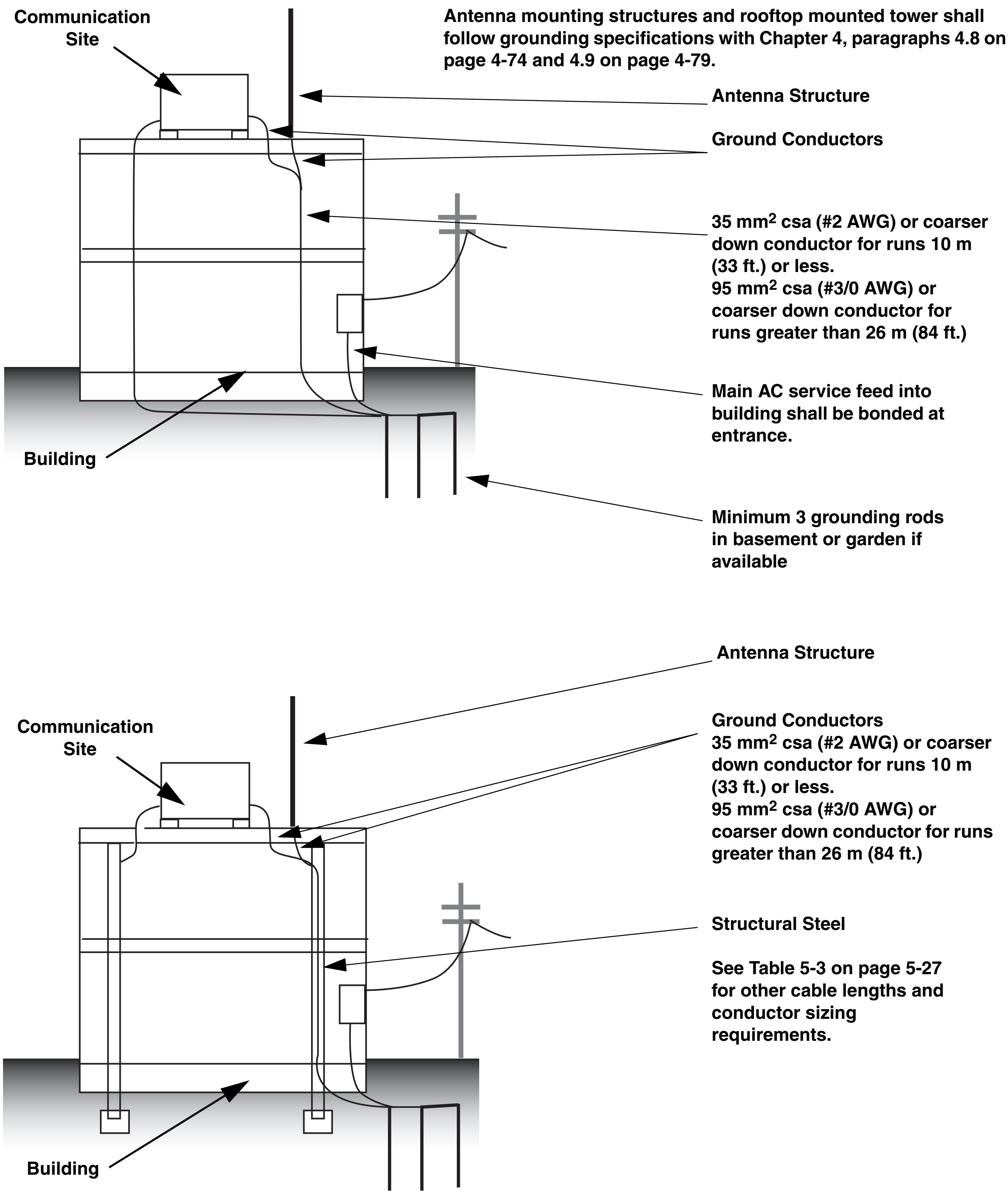


FIGURE 5-44 GROUNDING ROOFTOP INSTALLATIONS

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