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Regulatory

Jerry G. Jones, Manager

August 9, 2000

VIA HAND DELIVERY

Mr. David Waddell, Executive Secretary
Tennessee Regulatory Authority
460 James Robertson Parkway
Nashville, Tennessee 37243

Re: *BellSouth Request for Temporary Waiver of Physical Collocation in the Brentwood and Dickson Central Offices*
Docket Nos. 00-00357 and 00-00358

Dear Mr. Waddell:

In response to the questions raised by Mr. Carsie Mundy and Mr. Jerry Bennett during the recent central office walk-throughs, BellSouth provides the following information:

1. In the Dickson central office, can collocation equipment be located in Aisle 132 running through the middle of the 5ESS switching equipment area?

Answer: No, BellSouth adheres to the central office grounding requirements specified in the attached Bellcore Technical Reference TR-NWT-000295. These requirements specify the use of two ground planes, an isolated ground plane for the switching equipment and an integrated ground plane for the remainder of the equipment, including the building itself (*see* pp. 2-5, Definitions and Section 4.2, Requirements). Under this arrangement the placement of non-switch equipment within the isolated ground plane area would violate the specific requirements specified in Section 5 of this document. Therefore, it is not possible to locate transmission type equipment inside the isolated switching equipment ground plane due to both safety and service effecting concerns. In addition, the intended long-term use of this area is to restore proper front/back aisle clearance of the two 5ESS equipment lineups in Aisle 133.

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2. In the Brentwood central office, can collocation equipment be placed in the area adjacent to the planned BroadSlate caged collocation area on Aisle 117?

Answer: Yes, as suggested by Mr. Mundy and Mr. Bennett, by relocating the planned BroadSlate cage to within three feet of the 5ESS switching equipment in this area, BellSouth will be able to offer collocation of four contiguous collocation bays. The relocation of the BroadSlate cage will allow for the proper grounding of the collocation equipment without creating a safety hazard or service effecting condition as is the case described above in the Dickson central office. Based on the above, BellSouth will offer this area to the next applicant on the list.

3. In the Brentwood central office, can non-contiguous collocation equipment be located at the end of Aisles 120, 121, and 122 in what is now the staging and erection area?

Answer: Yes, although this area is less that an ideal area for collocation equipment because of the activity in the staging area. Also, none of these bays can be configured in a contiguous manner. BellSouth will offer space for four bays in this area to the next applicant on the list.

Although certain additional floor space will be made available for collocation in the Brentwood central office as a result of the walk-throughs, this central office still remains in a floor space exhaust condition. As was noted in BellSouth's response to the TRA's data request dated June 14, 2000 (item 3), the Brentwood central office has two applications for caged and three applications for cageless collocation outstanding. Even with the above-described additional space being made available for cageless collocation the applications for caged collocation cannot be fulfilled. Moreover, we have received an additional informal inquiry from another CLEC regarding the availability of collocation space in this central office.

If I can be of additional assistance, please call me at 214-3821.

Very truly yours,

Jerry G. Jones

Bellcore

Bell Communications Research

Technical Reference
TR-NWT-000295
Issue 2, July 1992

ISOLATED GROUND PLANES: Definition and Application to Telephone Central Offices

This document, TR-NWT-000295, Issue 2, July 1992, replaces TR-EOP-000295, Issue 1, November 1987.

This document, TR-NWT-000295, Issue 2, July 1992, replaces TR-EOP-000295, Issue 1, November 1987.

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Isolated Ground Planes: Definition and Application to Telephone Central Offices

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1. Introduction

1.1 Purpose and Scope

This document presents Bellcore's view of proposed generic requirements that describe grounding methods for metallic frames and electrical power supplies associated with Central Office (CO) electronic Stored Program Control Switching Systems (SPCSS) that are installed as an **Isolated Ground Plane.** Such switching systems typically provide local and intraLATA (Local Access and Transport Area) telephone services and access to interLATA and international carriers. Adherence to these requirements should help to meet the typical needs of BCCs.

The grounding and powering principles contained herein are also applicable to other telecommunications equipment designed and intended for installation in an isolated ground plane.

1.2 Organization

This Technical Reference (TR) consists of six major sections, an appendix, and a list of references. It covers the following key topics:

- Isolated Ground Plane
- Ground Window
- Stored Program Control Switching System (SPCSS)
- Frame Grounding
- Power Supply Grounding.

To help readers locate areas of interest, each section is summarized below.

Section 1 – Introduction
The Introduction states the TR's purpose and scope, introduces the major topics, and summarizes the contents.

Section 2 – Definitions
This section defines grounding terms and acronyms and how they are used by the suppliers and users of Central Office equipment.

Section 3 – Objectives
This section states the TR's objectives so that readers can better understand the requirements set forth in the sections that follow.

Section 4 – General Principles and Requirements
This section covers the following topics: reasons for grounding, isolated ground plane principles, frame and power supply grounding, grounding

conductors and connections, and induction effects on the isolated ground plane.

Section 5 – Specific Requirements

This section presents specific "how to" topics and techniques to show how isolated ground planes are developed.

Topics covered are: how to isolate and ground the frames that make up an isolated ground plane; how and where to establish a ground window; the size and type of wire to use; how to ground the principal power source; how to power the principal power source loads; how to establish ground reference buses; how to distribute power from external ac and dc power sources, other than the principal power source; illustrations showing specific ac and dc grounding principles; how to use a single power plant to power integrated and isolated ground plane loads; and how to correctly use three ground window configurations.

Section 6 – Performance Verification and Test Procedures

Once an isolated ground plane has been established, it becomes necessary to determine that guideline procedures and methods have been followed, and that correct wire sizes and bus bars have been used. This section establishes the methodology used to verify that the task has been properly performed and that the requirements in this TR have been met. The tests required for the isolated ground plane are: visual observations, insulation resistance tests, short circuit tests, and noise current tests.

Appendix

The appendix provides an overview of typical central office bonding and grounding system connections and illustrates typical overall frame grounding methods. This material is located in the appendix because much of it pertains to bonding and grounding connections in the central office integrated ground plane. As such, the material lies outside the scope of this TR.

References

This section lists key documents that provide general information on topics referred to in this TR.

1.3 Coloring

To assist the reader in identifying the basic elements on the schematic figures used in this TR, the following color scheme has been used:

- Red identifies the isolated ground plane(s) and associated wiring
- Green identifies the integrated ground plane(s) and associated wiring
- Blue identifies normal load current-carrying conductors.

1.4 Conventions for Generic Criteria

The ultimate determination of grounding and powering generic criteria for SPCSS that are installed as an isolated ground plane rests with the individual BCCs. This document presents Bellcore's view of these criteria, with consideration of their effect on equipment operation and reliability in the electromagnetic environment, and of the criteria intended to ensure the electrical safety of personnel. The generic criteria proposed in this document conform to the following definitions and conventions:

- Requirement – A feature or function that, in Bellcore's view, is necessary to satisfy the needs of a typical BCC. Failure to meet a Requirement may cause application restrictions, result in improper functioning of the product, or hinder operations. A Requirement contains the word "shall" and is flagged by the letter "**R**" in parentheses (**R**).
- Conditional Requirement – A feature or function that, in Bellcore's view, is necessary in specific BCC applications and may be reclassified as a Requirement by a user, depending on the applications environment in which the system is deployed. Conditional Requirements may depend on other Requirements, Objectives, or Conditional Requirements. A Conditional Requirement is flagged by the letters "**CR**" in parentheses (**CR**).
- Objective – A feature or function that, in Bellcore's view, is desirable and may be required by a BCC. An Objective represents a goal to be achieved. An Objective may be reclassified as a requirement in the future. An Objective is flagged by the letter"**O**" in parentheses (**O**) and contains the words "it is desirable" or "it is an objective." During a technical analysis using the criteria in this Technical Reference, it is Bellcore's intent that criteria indicated as Objectives be analyzed and results reported. Certain Objectives, where indicated in the text, will be analyzed and reported as Requirements after the designated date.

1.5 Reasons for Reissue

This document supersedes TR-EOP-000295, *ISOLATED GROUND PLANES, Definition and Application to Telephone Central Offices*, Issue 1, November 1987.

This new issue includes added sections on equipment frame interconnections within the isolated ground plane, the grounding of internal power supplies that power remote loads, the installation of receptacles powered from internal ac power supplies, the sizing of power plant frame grounding conductors, and "girdling" (the encirclement of a grounding conductor by a ring of ferromagnetic material).

Current in/ current out test procedures have been deleted from this issue.

This new issue includes an appendix that contains an overview of typical bonding and grounding connections in the central office integrated ground plane. This material, which was located in the main text in Issue 1, was retained because of its usefulness but was relocated to the appendix in this issue because it lies outside the scope of this TR.

2. Definitions

This section defines key grounding terms to help readers understand the contents of this TR. Whenever possible, the approved *National Electrical Code (NEC)*[1] definitions were used. Terms **not** covered by the NEC have been defined so that they agree with the usage developed by manufacturers and users.

Bonding*
The permanent joining of metallic parts to form an electrically conductive path that will ensure electrical continuity and the capacity to conduct safely any current likely to be imposed.

Central Office Ground Bus (CO GRD BUS)
A Central Office Bus that references the office principal ground point through the vertical equalizer. Usually, one of these buses is provided on each floor to permit the grounding of frames and power supplies as required. Larger buildings may have more than one of these buses.

Central Office Ground (CO GRD)
This is a system of conductors designed to provide a low impedance reference to the building's principal ground point. The system consists primarily of a vertical equalizer, CO GRD buses, and horizontal conductors. The system provides ground reference for frames and power supplies.

Ground*
A conducting connection, whether intentional or accidental, between an electrical circuit or equipment and the earth, or to some conducting body that serves in place of the earth.

Examples: The earth is considered a "ground" itself. It is the principal ground point, and all other planned and unplanned grounding connections lead to the principal ground point, the earth.

Grounded*
Connected to earth or to some conducting body that serves in place of the earth.

A ground grid or office grounding electrode system are examples of the conducting bodies that serve as a connection to earth.

* Terms marked with an asterisk (*) are consistent with the 1990 National Electrical Code.

Grounded Conductor*
A system or circuit conductor that is intentionally grounded.

Example: The conductor usually referred to as the "grounded conductor" is the one identified as "the neutral" in ac circuits and "the return conductor" in dc circuits.

Grounding Conductor*
A conductor used to connect equipment or the grounded circuit of a wiring system to a grounding electrode or electrodes.

Some examples of grounding conductors are as follows:

- The vertical equalizers (also called vertical risers) in buildings
- The grounding wires used to interconnect frames in a Stored Program Control Switching System (SPCSS)
- The Alternating Current Equipment Ground (ACEG) conductor, also called "the green wire," used to provide a fault current return path on grounded frames in ac power systems
- The equipment bonding jumper used to connect the grounded conductor (usually the neutral) to the ground bus in ac entrance switchgear
- The grounding wires used to interconnect frames in transmission equipment
- The grounding wire used to interconnect the shields of telephone cables.

NOTE – Grounding conductors and the equipment they interconnect are not ordinarily used to carry load currents under normal conditions.

Grounding Electrode Conductor*
The conductor used to connect the grounding electrode to the equipment grounding conductor and/or to the grounded conductor of the circuit at the service equipment or at the source of a separately derived system.

* Terms marked with an asterisk (*) are consistent with the 1990 National Electrical Code.

Grounding Electrode Conductor* (continued)

The following are examples of grounding electrode conductors:

- The conductor that interconnects the insulated –48 volt return bus and the main ground bus in a digital SPCSS
- In the ac entrance switchgear of a building, the conductor that interconnects the insulated neutral bus with the building grounding electrode or the water pipe
- In separately derived ac power sources such as stepdown transformers, the conductor that interconnects the frame of the transformer to the nearest ground reference.

Ground Window

A dimensional transition zone consisting of a sphere with a maximum three foot radius, which is the interface between the building's integrated ground plane and a given isolated ground plane. It is the opening (a window, if you will) where all ac and dc grounding conductors (including metallic raceways) serving an isolated ground plane "see" their last connection to the building's integrated ground plane before they are connected to the isolated ground plane frames. Any bond or connection to the main ground bus within the ground window shall be within three conductor feet of the center point of the sphere. More than one set of individual isolated ground plane frames may be connected to the main ground bus within a ground window.

After passing through the ground window, all the grounding conductors associated with the isolated ground plane are insulated from the building integrated ground plane because they have become a part of the isolated ground plane.

Conductors serving integrated ground planes that multiground the return side of the principal power source and are energized from the same power plant serving the isolated ground plane must be routed through the ground window and connected to the main ground bus. They do not have to be insulated from the building's integrated ground plane beyond the ground window.

* Terms marked with an asterisk (*) are consistent with the 1990 National Electrical Code.

Ground Window (continued)

NOTE – CCITT Recommendation K.27[2] refers to the Ground Window as the "Single Point Connection Window (SPCW)."

Horizontal Equalizers

The term "Horizontal Equalizers" has two separate definitions:

- Conductors of relatively low impedance that interconnect the battery return voltage terminals in separated distribution cabinets. These equalizers keep the return voltage difference between loads in separated frames at an acceptable value during periods of high loads.
- Conductors that extend from the CO GRD bus on each equipment floor to the ground systems of dc power plants and power distribution systems, and to equipment frames, racks, cabinets, and other metallic components on that floor.

The intended meaning of the term is usually determined by the context in which the term is used.

Incidental Ground

An unplanned grounding connection.

Examples: Incidental grounds usually occur during the mechanical assembly and installation of frames, raceways, piping, ducts, superstructure, and other conductive objects. When the frames are bolted to adjacent frames, a superstructure, and/or the superstructure-to-ceiling inserts in contact with building structural steel, they can form incidental ground connections.

NOTE – Incidental ground connections from building structural steel to isolated ground planes are not permitted.

Incidental grounds should not be depended on to produce a reliable electrical connection. Painted and oxidized surfaces and loose mechanical connections tend to insulate adjacent conducting surfaces.

Integrated Ground Plane

A set of interconnected frames that is intentionally grounded by making more than one connection to a ground reference. A multiplicity of these connections to ground reference are usually made from these frames to reduce the voltage drop to acceptable levels. Voltage drops occur when current flows through these frames during fault occurrences in the ac or dc power systems and when lightning strikes. Building structural steel, water pipes, ground rod systems, counterpoises, vertical and horizontal ground reference conductors, grounding wires, and metallic raceways form an integrated ground plane when bonded together by a multiplicity of deliberate and incidental connections.

Examples of an integrated ground plane are radio toll equipment frames and the main distributing frame.

> **NOTE** – CCITT Recommendation K.27[2] refers to the Integrated Ground Plane as the "Common Bonding Network (CBN)."

Isolated Ground Plane

A set of interconnected frames that is intentionally grounded by making only one connection to a given ground reference. This plane, taken as a conductive unit with all of its metallic surfaces and grounding wires bonded together, is insulated from contact with any other grounded metalwork in the building. During external fault occurrences in the ac or dc power systems and when lightning current flows in the building, none of these currents can flow in the isolated ground plane because of the single-point connection. Each SPCSS grounded in this way is defined as an Isolated Ground Plane.

Examples of isolated ground planes are electronic analog and digital switching systems.

Some users and suppliers call an "isolated ground plane" an "isolated ground zone."

> **NOTE** – CCITT Recommendation K.27[2] refers to the Isolated Ground Plane as the "Isolated Bonding Network (IBN)."

Main Ground Bus (MGB) A bus bar (or bars) located within the ground window that provides the single point of connection between the building's integrated ground plane and the isolated ground plane.

NOTE – CCITT Recommendation K.27[2] refers to the Main Ground Bus as the "Single Point Connection Bus-Bar (SPCB)."

Office Principal Ground Point Bus (OPGPB) A ground bus located near but external to the ac entrance switchgear. It serves as a central connection point for conductors such as those listed below.

- The vertical equalizer(s)
- A bond to the ac entrance switchgear enclosure
- A bond to the ground bus inside the ac entrance switchgear enclosure
- Bonds to structural steel
- Bonds to grounding electrodes
- Other bonds to equipment frames requiring ground reference.

Typical grounding electrodes are any combination of:

- Water pipes (see the Appendix for limitations on use)
- Ground rings or grids
- Ground rods or ground rod arrays
- Supplementary ground fields
- Structural steel ground grids.

NOTE – CCITT Recommendation K.27[2] refers to the Office Principal Ground Point Bus as the "Main Earthing Terminal."

Raceway* An enclosed channel designed expressly for holding wires, cables, or bus bars, with additional functions as permitted in this Code (the NEC[1].)

Separately Derived Power Supply A power supply that has electrical isolation between its input and output current-carrying members.

NOTE – This definition is similar to the NEC definition of "Separately Derived Systems." See Section 250–5(d) of the NEC.[1]

* Terms marked with an asterisk (*) are consistent with the 1990 National Electrical Code.

Separately Derived Power Supply (continued)

Examples of a separately derived power supply include

- A standby ac reserve arranged so that the neutral is switched
- Power supplies with isolation between input and output such as transformers, inverters, and converters.

Two examples of power sources that are not separately derived are:

- Standby ac reserve power units where the neutral is not switched
- Autotransformers.

Serial versus Radial Grounding

A system is serially grounded when a set of isolated ground plane frames in the system is connected in series from its associated ground window. A system is radially grounded when two or more sets of frames of the same system are grounded by the use of separate grounding conductors from a common ground window.

Examples: Figure 5-1 shows simplified examples of serial and radial frame grounding.

Single-Point Ground (for Frames)

A method used to ground a set of frames for a given electronic entity that can have only one grounding connection from the given set of frames to a planned ground reference. Because this set of frames does not have multiconnections (either planned or incidental) to other ground references, it is classified as an isolated ground plane.

Example: The single-point ground principle is used in the isolated ground planes of electronic analog and digital switching systems.

> **NOTE** – CCITT Recommendation K.27[2] refers to the Single Point Ground as the "Single-Point Connection (SPC)."

Single Point Ground (for Power Supplies)

When one current-carrying member of a separately derived power source is connected to a ground reference at only one point, it is single point grounded. (In contrast to this, grounded conductors having more than one connection to a ground reference along their length are classified as multigrounded systems.)

Single Point Ground (for Power Supplies) (continued)

Examples of single-point grounded power supplies are the following:

- The 48-volt power source supplying isolated ground plane digital switching loads is grounded by a single connection from the insulated –48-volt return bus in the power plant to the main ground bus within the ground window serving the system.
- The ac power service to a building is grounded by a single connection from its neutral to the building grounding electrode.

An example of a multigrounded system is a 48-volt power source that supplies integrated ground plane electromechanical switching system loads. These loads are grounded at the power source (the –48-volt return bus in the power plant is not insulated) as well as at the loads where multiple connections to grounded frames are made along the length of the –48-volt return conductor.

Solidly Grounded

A method of grounding either a power supply or a frame that uses a grounding wire connection in which NO additional impedance has been intentionally connected in series with the grounding path.

NOTE – This term usually describes how a power supply should be grounded. Other methods of grounding power supplies include ungrounded, resistance grounded, reactance grounded, and resonant grounded.

Vertical Equalizer (also called Vertical Riser)

The main vertical grounding conductor used to obtain ground reference between the CO GRD BUS on each floor and the office principal ground point in a building. The conductor should be continuous and should extend through the height of the building. Where necessary, the vertical equalizer may be extended or spliced by means of irreversible compression-type connectors listed for the purpose or by the exothermic welding process. This conductor is bonded to the office principal ground point bus. On each floor, the CO GRD BUS connects to the vertical equalizer to form an effective earth reference.

3. Objectives

This TR provides a set of grounding criteria for isolated ground planes and their associated power supplies. These criteria are intended to assist in accomplishing the following:*

a. Ground components by methods that will guard personnel from electrical shock hazards

b. Help ensure reliable operation and reduce equipment maintenance

c. Promote standardized practices for grounding Stored Program Control Switching Systems (SPCSS) from site to site. This will help simplify the maintenance and auditing procedures of these systems.

d. Enable overcurrent protection devices (fuses and circuit breakers) to clear short circuits rapidly and safely

e. Prevent external sources of foreign currents (noise currents) that can damage sensitive equipment or disrupt its operation from flowing in and out of the isolated ground plane

f. Reduce to acceptable values the voltage stress that can appear between the isolated and integrated ground planes when lightning or short-circuit currents flow through the integrated ground plane

g. Reduce the voltage stress that can appear between the –48 volt return conductor and the isolated ground plane (in effect, this stress appears across the insulation of the loads) when lightning or short-circuit currents flow through the integrated ground plane

h. Control the flow of short-circuit current in susceptible frames within the isolated ground plane. This helps prevent equipment misoperation or damage.

i. Reduce internal noise currents that can interfere with proper equipment operation if allowed to flow on the isolated ground plane

j. Meet *National Electrical Code (NEC)*[1] requirements for ac power

k. Help ensure low-impedance grounding-wire and bus-bar connections for the lifetime of the installation.

* See disclaimer on page iii.

4. General Principles and Requirements

4.1 Reasons for Grounding

4.1.1 Personnel Safety

(R) The grounding and bonding of metallic frames and raceways shall minimize potential differences between these structures when lightning or fault currents flow.

(R) The grounding of power sources should prevent system voltages from permanently appearing on frames that personnel can touch. When faults to frames do occur, the grounding system shall permit protection devices to operate quickly and safely.

(R) All metallic parts of the isolated ground plane shall be grounded so that shock voltages are not transmitted to personnel.

(R) The electrical safety criteria of Section 7 of TR-NWT-001089)[3] shall be met.

4.1.2 Equipment and Distribution Circuit Protection

(R) To prevent electrical fires and limit damage to equipment and associated circuit conductors:

a. The grounding system shall provide a low-impedance path for lightning currents to flow to earth when lightning strikes.

b. The grounding system shall provide fault-current paths of sufficiently low impedance and adequate current-carrying capability so that circuit breakers and fuses can quickly and safely disconnect the faulted circuit.

4.1.3 Equipment Operation

(R) The grounding system shall minimize the effects of noise disturbances originating inside or outside the isolated ground plane on the equipment operating therein.

4.1.4 Conducted Noise Reduction

(R) The grounding system shall prevent noise currents from external sources from being conducted into the isolated ground plane.

4.1.5 Reference Buses

(O) It is desirable that the grounding system provide noise-free reference buses throughout the isolated ground plane so that transmitting and receiving circuits, which require an equalized ground reference, can operate with minimum interference.

4.1.6 Electrostatic Discharges (ESD)

(R) The effects of ESD shall be minimized by maintaining low-impedance paths between grounded points throughout the isolated ground plane. No metallic parts of the isolated ground plane shall be capable of storing electrostatic charges.

4.1.7 Reliability

(R) The grounding system shall consist of wiring, buses, connectors, and connections that resist deterioration and require minimal maintenance for the lifetime of the equipment contained in the isolated ground plane.

4.2 Isolated Ground Plane Principles

(R) All the frames that house an electronic SPCSS (see Section 1.1) shall be treated as an isolated ground plane. Therefore, all further references to SPCSS frames shall assume that they are an isolated ground plane.

4.2.1 The Simplified Isolated Ground Plane

Figure 4-1 illustrates an isolated ground plane in its simplest form. A set of frames housing electronic circuits is initially insulated from all elements of the integrated ground plane. Then a single point of connection is made through a ground window from the electronic entity to the integrated ground plane.

4.2.2 Noise Current Flow in the Isolated Ground Plane

When an SPCSS is treated as an isolated ground plane, external noise currents that could produce voltages that damage and upset the system circuitry cannot flow in the frames. Some sources of external noise currents are the following:

a. Lightning strikes

b. External power faults

c. Filters that are connected from line to ground

d. Multigrounded ac and dc power sources

e. Surge protectors that are connected from line to ground

f. Improper load connections.

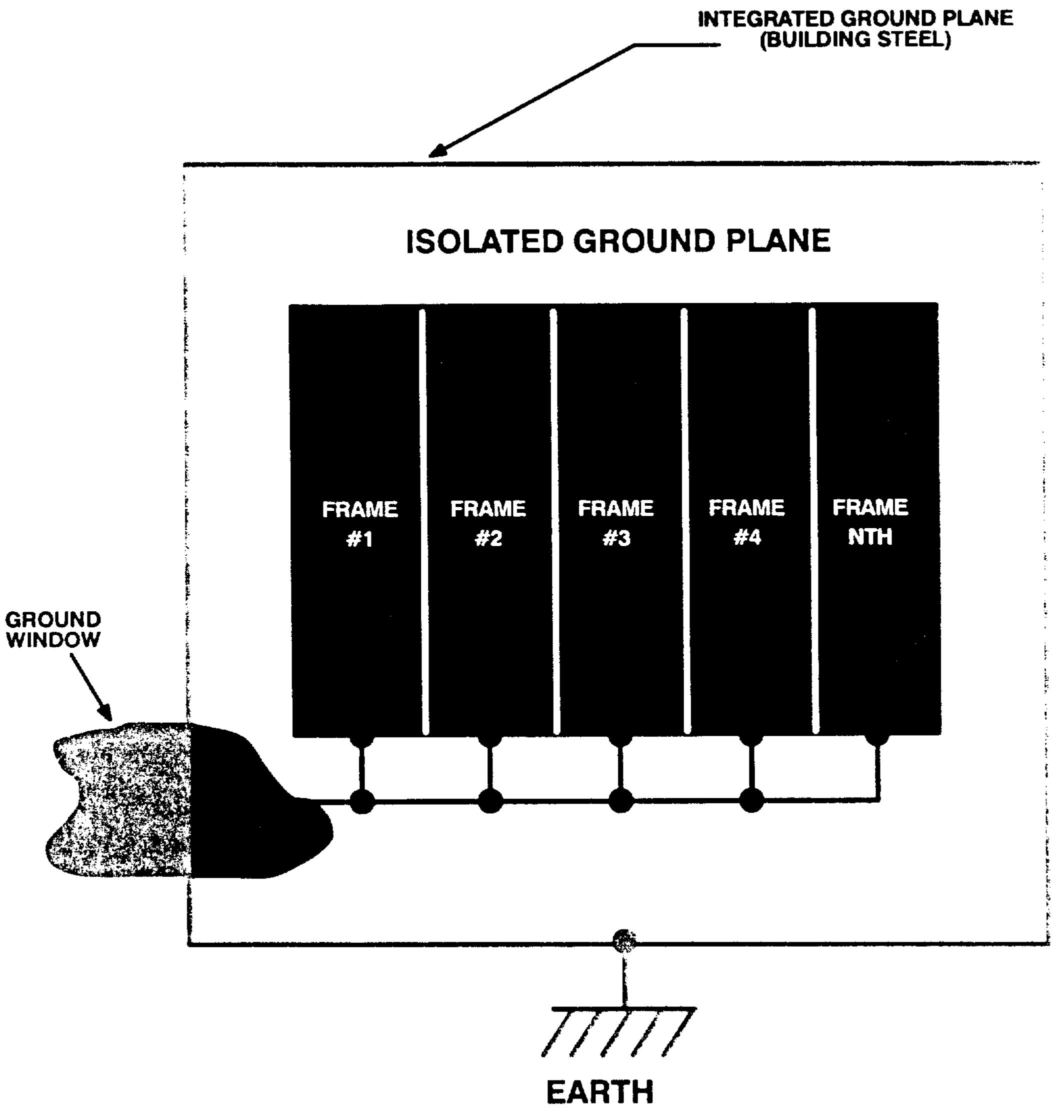


Figure 4-1. Simplified Isolated Ground Plane

4.3 Power Supply Grounding Methods

(**R**) Generally, all power sources serving an isolated ground plane shall be single-point solidly grounded.

Exceptions to this rule are:

a. When the principal power source has a return bus that is **not** insulated from the plant's frame and a part of this bus is used as the **ground window** and modified per Section 5.10.2.

b. Return conductors serving integrated ground plane loads (for example, radio toll and crossbar systems) from the same power plant that serves isolated ground plane loads are permitted to multiground the power source at the loads housed in the integrated ground plane if those return conductors are routed through the ground window and bonded to the MGB in accordance with Section 5.5.

4.3.1 Multigrounded Power Sources

(R) Generally, multigrounded power sources (sources with one load current-carrying member grounded at more than one point along its length) shall not be used to power isolated ground plane loads. Section 4.3 lists exceptions.

4.3.2 DC Power Supplies

(R) All dc power supplies serving an isolated ground plane shall be single-point grounded. Section 4.3 lists exceptions.

4.3.2.1 Grounding Location

a. **(R)** The return side (usually the positive terminal) of the principal power source shall be grounded with a separate grounding electrode conductor at the MGB associated with the isolated ground plane. The principal power source is classified as an external power source.

b. **(R)** Other external dc power sources serving both integrated and isolated ground plane loads shall have their conductors routed through the ground window and their return conductors bonded to the MGB.

c. **(R)** Internal dc power supplies (usually dc-to-dc converters and rectifiers) shall be grounded at the **nearest** internal reference ground bus. (See Section 5.6.1 for exceptions.)

4.3.2.2 Return Conductors

(R) Return conductors are the grounded conductors in dc power supplies. They shall not be used as grounding conductors.

4.3.2.3 Isolated Ground Plane Grounding Conductors

(R) Grounding conductors shall be used only to ground power supplies and frames. They shall not be connected in parallel with return conductors. Furthermore, grounding conductors shall not conduct normal load currents. They shall conduct line-to-ground fault currents only. Their impedance shall be low enough to permit the faulted circuit to be cleared quickly and safely. The grounding conductors shall take paths that are as direct and as straight as possible without any sudden changes in direction. If the direction must change, it shall do so gradually with a minimum curvature radius of 1 foot.

4.3.2.4 Power Distribution Cabinets (PDCs)

(R) The frames of the PDCs used to distribute local dc power to isolated ground plane loads shall be part of the isolated ground plane.

4.3.3 AC Power Supplies

(R) All separately derived ac power supplies shall be solidly grounded.

4.3.3.1 Safety Requirements

(R) All component parts used in the ac power distribution system serving the isolated ground plane shall be listed by a Nationally Recognized Testing Laboratory (NRTL) and wired in accordance with the appropriate requirements of the most recent edition of the *National Electrical Code (NEC)*.[1]

4.3.3.2 Raceways

(R) All ac branch circuits serving the isolated ground plane shall be housed in metallic raceways from source to load. Each raceway shall be joined to form a continuously conductive grounding path.

4.3.3.3 Use of AC Equipment Grounding (ACEG) Conductor

(R) An ACEG conductor shall be provided in all raceways housing ac circuits from source to load. This conductor shall be insulated and identified with a green color.

4.3.3.4 ACEG Requirements

a. **(R)** All grounding conductors and metallic raceways associated with external ac power that feeds loads within the isolated ground plane shall be routed through the ground window and bonded to its MGB.

b. **(R)** All grounding conductors shall be connected to each junction box that they pass through and shall terminate on the junction box containing the load their circuit serves.

NOTE – A junction box refers to a pull-box, outlet/receptacle box, or any similar metallic enclosure.

4.3.3.5 Single-Point Grounding of AC Power Supplies

(R) All separately derived ac power systems shall be solidly grounded at their immediate outputs and only at that one point. The grounded conductor, usually called the neutral, shall not be grounded at any other point along its entire length.

If the supply is not part of the isolated ground plane, a second connection shall be made from the frame containing the power supply to the nearest ground reference, which is building structural steel, CO GRD, or the integrated ground plane side of the MGB.

4.3.3.6 Grounding Internal AC Power Supplies

(R) The output of each separately derived internal ac power supply shall be grounded by directly connecting its designated neutral to the closest ground reference in the isolated ground plane. **NO** further connections of the neutral to a ground reference shall be made.

4.3.3.6.1 Grounding Internal AC Power Supplies That Power Remote Loads

(R) It is recognized that separately derived internal ac power supplies are sometimes used to supply power to isolated ground plane equipment that is remote from the contiguous set of equipment frames that contain the SPCSS and the separately derived internal ac supply. In this case, the power supply shall be considered the source of a separately derived system of premises wiring, and the grounding requirements of NEC Sections 250–5 (d) and 250–26 shall apply. A grounding electrode conductor sized in accordance with NEC Section 250–94 shall be used to interconnect the power supply's grounded output terminal to an appearance of the office grounding electrode system. This shall be accomplished by routing a separate conductor from the power supply's grounded output terminal through the ground window, bonding it to the MGB, and then connecting it to the CO GRD bus on the same floor as the ground window.

Bellcore does not recommend the powering of remote loads in this manner because it extends the isolated ground plane, via the inverter-supplied premises wiring, to a location remote from the contiguous set of isolated equipment frames. Inadvertent violations of the isolated ground plane can occur along the route of the wiring and at the load end.

4.3.3.7 General-Purpose Receptacles

(R) Every receptacle mounted on the isolated ground plane shall be the standard type that connects its grounding terminal to its frame.

4.3.3.7.1 Receptacles Powered From Internal AC Power Supplies

(R) Receptacles that are mounted on the isolated ground plane and are powered from separately derived internal ac power supplies shall not be accessible except by way of doors or covers. Receptacles powered from separately derived internal ac power supplies are not intended for general use, but are intended to supply cord-and-plug connected equipment that is part of or peripheral to the SPCSS, or to supply test equipment intended for SPCSS maintenance.

4.3.3.8 Special-Purpose Receptacles

(R) Special-purpose receptacles, defined as receptacles in which the grounding terminal is purposely insulated from the receptacle's frame, shall not be used.

4.4 General Grounding Conductor and Connection Requirements

4.4.1 For DC Conductors

(R) The dc grounding conductors shall be made of copper. Aluminum conductors shall not be used. Conductors made of wire, bus bar, or braided strap are acceptable. When wire is used, it shall be stranded to accommodate the use of compression connectors. The size of the grounding conductors shall be as specified by the SPCSS supplier. No wire or equivalent frame-grounding conductor shall have a cross-sectional area less than that of a No. 6 AWG stranded wire. Any dc grounding conductors used to ground frame members of the isolated ground plane can be bare or insulated. All other conductors shall be insulated.

4.4.2 For AC Equipment Ground (ACEG) Conductors

(R) ACEG conductors (sometimes referred to as the "green wire" ground) shall be made of the same metal that is used for their associated phase and neutral leads (copper or aluminum). All ACEG conductors shall be insulated and identified with a green color. The size of the ACEG shall be in accordance with Section 250–95 of the most recent edition of the NEC.[1]

4.4.3 Connections

(R) Because of different characteristics of copper and aluminum, connection devices shall be suitable for the material of the conductor and shall be properly installed and used. Conductors of dissimilar metals shall not be intermixed in a terminal or splicing connector where physical contact occurs between dissimilar conductors (such as copper and aluminum; copper and copperclad aluminum), unless the device is listed as being suitable for the purpose and conditions of use. Materials such as fluxes, inhibitors and compounds, where employed, shall be suitable for the use and shall be of a type that will not adversely affect the conductors, installation, or equipment.

(R) Required grounding conductors and bonding jumpers shall be connected by compression-type connectors. Connecting devices or fittings that depend solely on solder shall not be used.

(R) Nonconductive coatings (such as paint, lacquer, and enamel) on equipment to be grounded shall be removed from threads and other contact surfaces to ensure electrical continuity.

(a) Terminals

(R) Connection of conductors to terminal parts shall ensure a thoroughly good connection without damaging the conductor and shall be made by means of crimp-type connectors.

(R) Terminals for more than one conductor and terminals used to connect aluminum shall be so identified.

(b) Splices

(R) Conductors shall be spliced or joined with compression-type splicing devices suitable for the purpose or by brazing or welding with a fusible metal or alloy. All splices, joints, and the free ends of conductors shall be covered with an insulation equivalent to that of the conductors or with an insulating device suitable for the purpose.

4.5 Induction Effects

Induction effects on the isolated ground plane may be minimized by routing lightning and fault-current-carrying conductors as far away as practicable from the isolated ground plane.

4.5.1 Lightning and Fault Current Carrying Conductors

(R) The following types of conductors shall be routed a minimum of 3 feet from the isolated ground plane frames:

a. The grounding wires going from the MGB and the CO GRD to the main distributing frame
b. Waveguides and coaxial cables from tower-mounted antennas
c. Metallic raceways from other systems.

4.5.2 Nearby Integrated Ground Plane Members

(R) All integrated ground plane conductive members located within 6 feet of the isolated ground plane shall be bonded to its MGB to minimize surge potential differences between nearby members of the two ground planes. Such integrated ground plane members include, but are not limited to, the following:

a. Metallic stands and desks

b. Electromechanical equipment frames

c. Ironwork

d. Lighting fixtures that are not part of the isolated ground plane. (Lighting fixtures should be located in the integrated ground plane where possible —see Section 5.1.2.4.)

e. Air ducts.

5. Specific Requirements

5.1 Isolated Ground Plane Frames

5.1.1 One Conductive Unit

(R) The set of frames designated as the isolated ground plane shall be one conductive unit. All of its metallic surfaces and grounding wires shall be bonded together with planned electrical connections. Incidental grounds are not acceptable electrical connections. Lighting fixtures that are part of the isolated ground plane, receptacle housings, end guards, raceways, and other peripheral parts of the isolated ground plane shall be part of the one conductive unit.

5.1.2 Insulation Resistance

(R) All frames that are part of the isolated ground plane shall be installed using insulating material in a way that insulates them from the integrated ground plane (building structural steel and all other elements of the integrated ground plane). The insulating material shall have a dielectric strength not less than that of nylon (400 volts/mil). Before any MGB or power connections are made to the isolated ground plane, and after all hold-down and fastening hardware is installed, the insulation resistance between the isolated frames and the integrated ground plane shall be verified to be 100,000 ohms or more (see Section 6.4). The isolated ground plane shall be isolated from the building's integrated ground plane by using insulators between points where metalwork that is common to the isolated ground plane must be fastened to metalwork and concrete that is common to the integrated ground plane. Typical fastening points include anchor bolts, bottom of frames, superstructure supports, lighting fixtures, and other hardware, as discussed below.

5.1.2.1 Anchor Bolts

(R) Isolated ground plane anchor bolts might touch grounded structural metal in the floor. Therefore, these bolts shall be insulated from the isolated ground plane.

> **NOTE –** Concrete by itself is a fairly good conductor under some circumstances.

5.1.2.2 Bottom of Frames

(R) If there is any possibility that the bottom of the frames (other than at hold-down fastener locations) in the isolated ground plane might come in contact with the floor or with structural metal, then a sheet of material having adequate insulation shall be placed between the frames and the floor.

5.1.2.3 Superstructure Supports

(R) Superstructure supports to the isolated ground plane, where used, shall be insulated.

5.1.2.4 Lighting Fixtures, etc.

(O) It is desirable that lighting fixtures be part of the integrated ground plane. Lighting fixtures, raceways, and cable racks that are part of the isolated ground plane shall be insulated from the integrated ground plane. Figure 5-5 illustrates the connection of lighting fixtures that are part of the isolated ground plane.

5.1.3 Frame-to-Frame Connections

(R) Reliable frame-to-frame grounding connections shall be made. Two typical ways of making such connections are as follows:

a. Route a minimum No. 6 AWG bare or insulated stranded copper wire along each frame lineup. Using compression connectors, connect the grounding wire to a grounding lug supplied on each frame.

b. Using a bare copper bus connected to each frame, interconnect each bus section with a crimped, braided strap. The cross-sectional area of the bus and the braid shall be equal to or greater than No. 6 AWG stranded copper wire (about 0.027 square inches).

5.1.4 Grounding Among Groups of Frames

(R) Groups of frames in an isolated ground plane shall be grounded by either of two basic methods:

- A method that deliberately avoids the formation of frame ground loops within the isolated ground plane (see Section 5.1.4.1 on serial and radial grounding connections).
- A method that deliberately permits the interconnection of groups of frames in such a way that numerous frame ground loops are formed (see Section 5.1.4.2 on interconnected frames).

(R) Either method is acceptable in accordance with the vendor's grounding design strategy. The vendor shall state the method that is to be employed.

(R) The size of the grounding conductor used between each group of frames and the MGB shall be a minimum of No. 1/0 AWG.

5.1.4.1 Serial and Radial Connections Within the Isolated Ground Plane

(R) Where serial or radial frame grounding is used (see Figure 5-1), no additional ground-wire connections that would cause a ground loop to be formed shall be made between the sets of frames. Figure 5-2 illustrates several types of ground loops that are not permitted to be formed when serial or radial grounding is used. Caution shall be taken to ensure that loops are not inadvertently formed by grounded cable shields, metallic cable trays, metal electrical conduits, or other means when serial or radial grounding is used. Additional considerations for avoiding loops are as follows:

a. If transmitter or receiver circuits are within the respective radially grounded sets of frames, then these circuits should have their outputs isolated to avoid closing an inductive loop.

b. Electrostatic shields that might be used to enclose interconnecting wires between radially grounded sets should be grounded to the frame at only one end.

c. Magnetic shields that might be used to enclose interconnecting wires between radially grounded sets should be run close to the frame-grounding wire. The shield itself should pass through the ground window and be connected to the MGB.

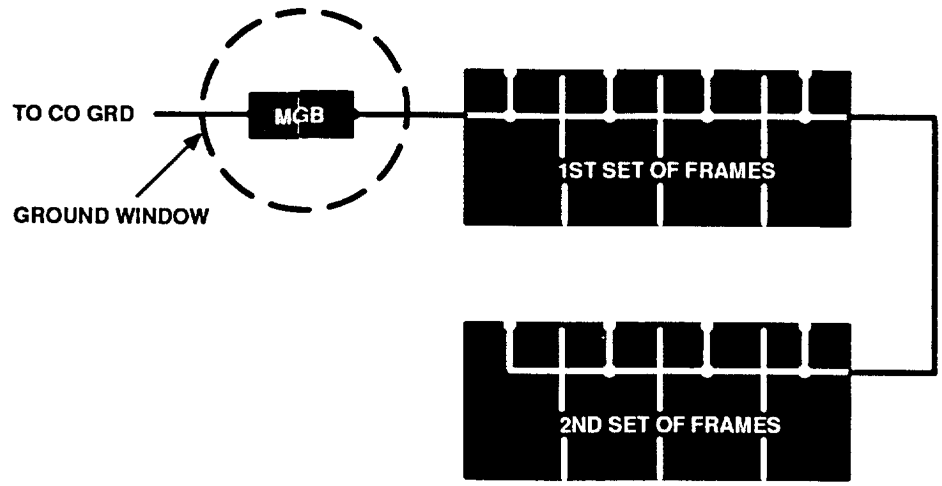
5.1.4.2 Frame Interconnections Within the Isolated Ground Plane

Groups of frames within an isolated ground plane may be interconnected through the use of cross-aisle interconnections that connect the frames of one frame lineup to the frames of a second frame lineup. Cross-aisle metallic cable trays, metallic power conduits, metallic cable shields, and deliberate cross-aisle bonds may be used to interconnect groups of frames within an isolated ground plane.

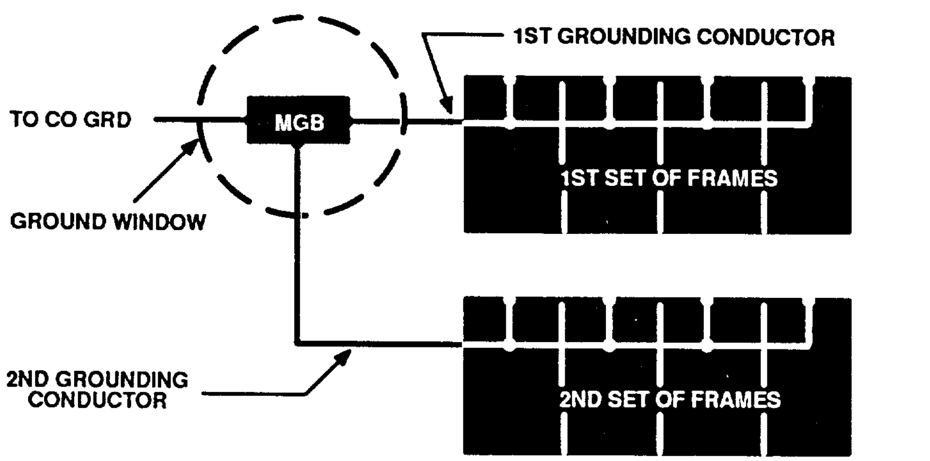
5.1.5 Limits on the Number of Floors an Isolated Ground Plane Can Occupy

a. **(R)** A given isolated ground plane shall occupy no more than three floors.

b. **(R)** Only one ground window and one principal power plant shall serve the isolated ground plane. The ground window shall be located on the middle floor of the three floors.



(a) SERIAL GROUNDING



(b) RADIAL GROUNDING

Figure 5-1. Simplified Examples of Serial and Radial Frame Grounding

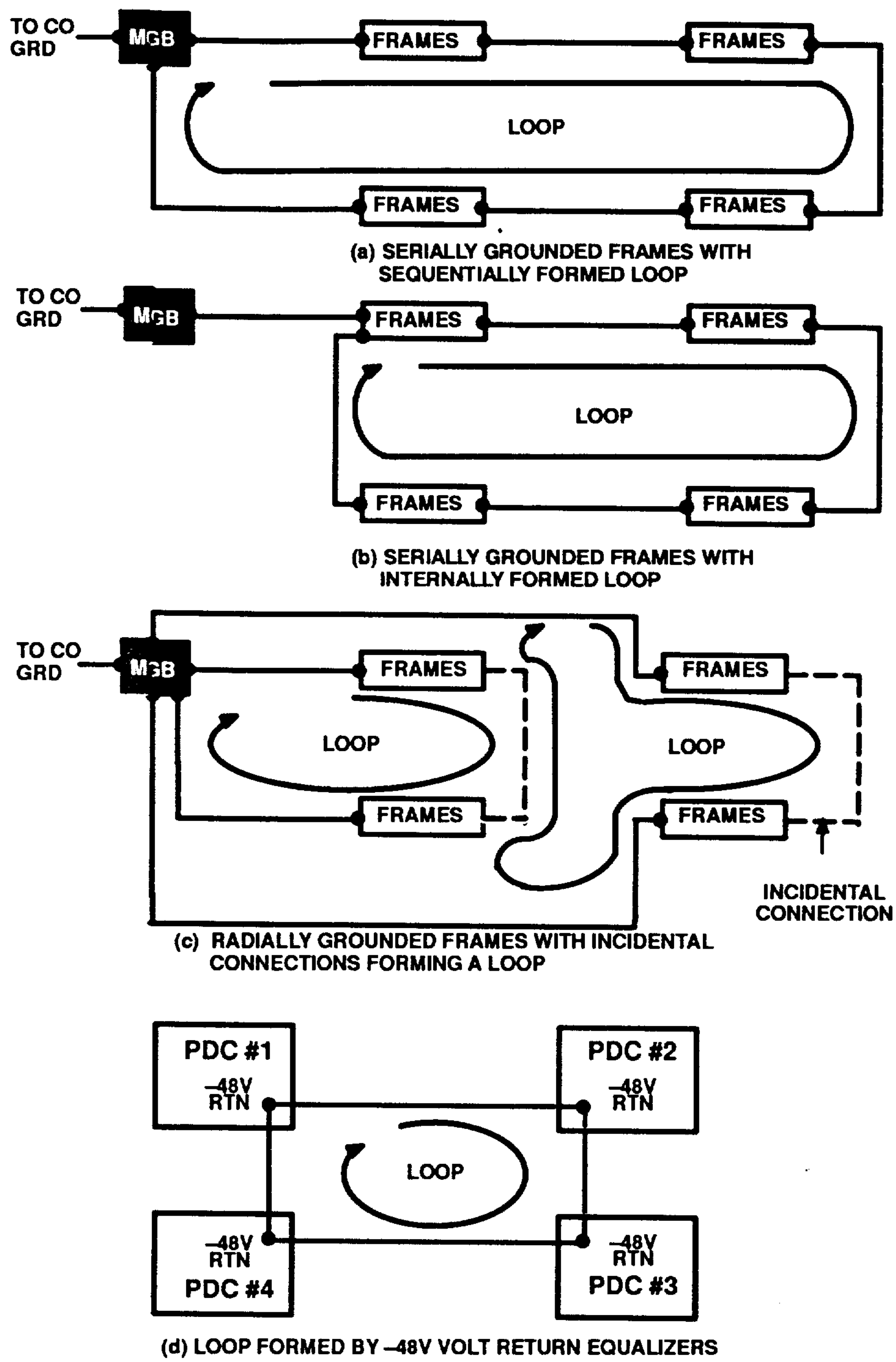


Figure 5-2. Examples of Loops Not Permitted on Isolated Ground Planes Using Serial or Radial Frame Grounding

5.1.6 Peripheral Equipment Frame Grounding

(O) It is desirable that isolation techniques, such as optical fiber, current loop, or back-to-back modems be used between the peripheral equipment and the isolated ground plane frames, thus enabling the peripheral equipment to be grounded as part of the integrated ground plane and to be powered from commercial ac power.

(R) Peripheral equipment frames (e.g., teletype printers, video and hard-copy terminals) that are connected with grounding wire to the isolated ground plane shall be treated as if they were an integral part of the isolated ground plane. Power for these loads shall come from sources within the isolated ground plane or from sources routed through the ground window, as per Section 5.7.2. The grounding wires associated with these power sources shall be used to extend ground reference to the peripheral equipment's frame without making contact with the integrated ground plane. Peripheral equipment grounded in this manner shall be within one floor of the ground window serving the isolated ground plane.

(R) Peripheral equipment located more than one floor away from the ground window serving the isolated ground plane shall not have any metallic grounding connections to the isolated ground plane members. If this type of equipment must be treated as an isolated ground plane and it is desirable to power it from the same principal power source that powers the isolated ground plane, it shall be electrically isolated from the principal power source through input/output isolated dc-to-dc converters. A second ground window on the "secondary" side of the dc-to-dc converters then can be established to ground the peripheral equipment frames. This "new" ground window shall be located within one floor of the peripheral equipment.

5.2 Establishing a Separate Ground Window

(See Section 5.10 for requirements when a portion of the principal power plant's return bus is used as a ground window.)

(R) A ground window, as previously defined (see Section 2), shall be established to serve the isolated ground plane. A copper bus (or buses) called the main ground bus (MGB), shall be located within the ground window to provide a place where various required connections can be made. The MGB shall **not** be mounted on any of the isolated ground plane frames.

> **NOTE** – The MGB within the ground window should be clearly identified by stenciling or other means.

(R) To prevent lightning and fault currents from other sources from flowing through the MGB, it shall be mounted on insulators so that it is insulated from the building integrated ground plane. The ironwork supporting the MGB, however, must be bonded to the MGB. Care must be taken to ensure that this bond is made in accordance with the sequencing requirements illustrated in Figure 5-3 (conductor #8).

(R) Only one ground window shall be associated with the principal power source serving the isolated ground plane.

More than one set of isolated ground plane frames may be served from a single ground window (see Section 5.10).

5.2.1 Dimensions

(R) The ground window's dimensions shall be those of an imaginary sphere with a maximum radius of 3 feet.

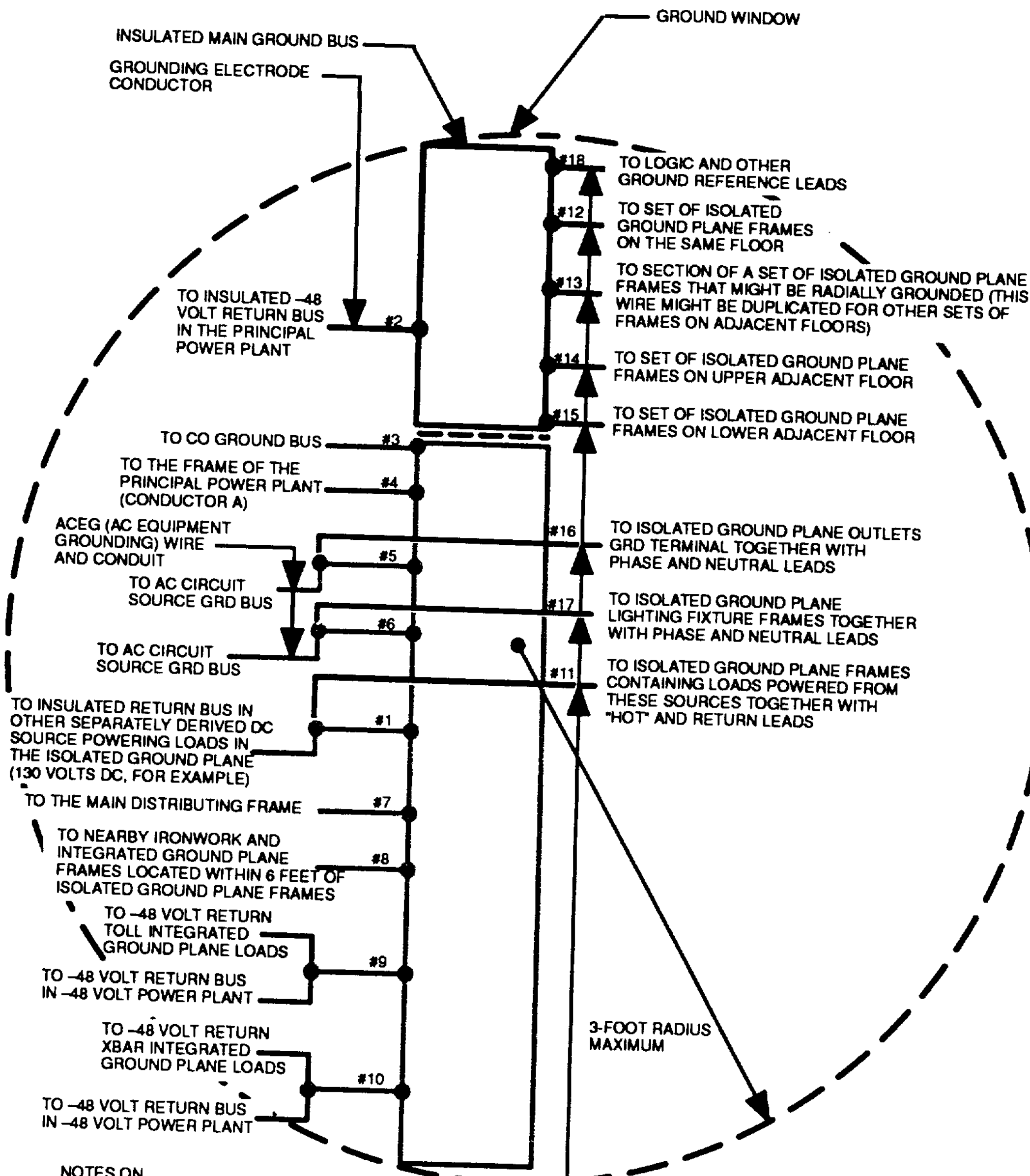
5.2.2 Location

(R) The ground window should be located as close as possible to the isolated ground plane(s) it serves. Vertically, it shall be no more than one floor from the isolated ground plane. Horizontally, the ground window shall be no further than 100 feet (straight line distance) from the floor central office ground (CO GRD) or 100 feet (straight line distance) from the furthest member in the isolated ground plane. In no case, however, shall the furthest unit of equipment in the isolated ground plane be more than 200 conductor feet from the floor CO GRD bus.

5.2.3 Ground Window Connections

(R) A number of possible connections can be made on the MGB within the ground window, depending upon the needs of the various installations. Figure 5-3 shows typical detailed connections. The MGB can be thought of as the transition conductor between the integrated and isolated ground planes. The sequence of connections shown in Figure 5-3 should be followed. Table 5-1 identifies sizes and classifies the conductors shown in Figure 5-3.

(R) No connections shall be made between the isolated ground plane and the integrated ground plane other than through the MGB. All conducting materials that are part of the isolated ground plane such as cable racks, wire troughs, conduits, armored cable, enclosed conductors, and the SPCSS frames shall be insulated **and kept** insulated from the integrated ground plane.



NOTES ON COLORING:

RED IDENTIFIES CONDUCTORS ASSOCIATED WITH THE ISOLATED GROUND PLANE.
GREEN IDENTIFIES CONDUCTORS ASSOCIATED WITH THE INTEGRATED GROUND PLANE.
BLUE IDENTIFIES LOAD CURRENT-CARRYING CONDUCTORS.

Figure 5-3. Typical Sequence of Connections to a Separate Ground Window

Table 5-1. Tabulation of Typical Ground Window Connections

Conductor identification (See Figure 5–3)	Section of TR where conductor is discussed	Required in all plants		Required in some plants		Minimum wire size (AWG)
		Yes	No	Yes	No	
#1 External power sources grounding conductors	5.7.1		X	X		# 6
#2 Principal power supply grounding electrode conductor	5.4.2	X				750 MCM
#3 Main ground bus to CO GRD connection	5.2.2	X				750 MCM
#4 Principal power plant frame grounding wire (Conductor A)	5.3.1		X	X		See Section 5.3.1
#5, #6 External power sources grounding conductors	5.7.2		X	X		# 6
#7 Main distributing frame grounding wire	Appendix		X	X		# 1/0
#8 Grounding wires for nearby ironwork and integrated ground plane frames within 6 feet of isolated ground plane	4.5.2		X	X		# 6
#9 Multigrounded toll load –48v return load conductor	5.9.3		X	X		Same size as the load conductor (maximum #1/0)
#10 Multigrounded Xbar –48v return load conductor	5.9.3		X	X		Same size as the load conductor (maximum #1/0)
#11 Continuation of grounding conductor (and conduit) from associated external power sources	5.7.1			X		Same size as associated "hot" and return conductors
#12, #13, #14, #15 Isolated ground plane grounding conductors	5.1.4, 5.1.5	X				# 1/0 Minimum
#16, #17 Continuation of grounding conductor (and conduit) from associated external power sources	5.7.2			X		Sized per NEC Section 250-95
#18 Logic and other ground reference leads in isolated ground plane			X	X		Per vendor requirement

5.3 Grounding Conductor Requirements

(R) Grounding conductors shall be used only to perform the following:

a. Ground frames and power supplies
b. Safely conduct lightning currents
c. Safely conduct the current produced from line-to-frame faults.

Framework grounding conductors shall not be used to conduct normal load currents.

The impedance of any particular grounding conductor path shall be low enough to permit at least ten times the rated current of the circuit's associated protective device to flow when line-to-frame faults occur. The calculations that determine the impedance that meets this condition shall be based on the longest possible fault current path and the lowest working circuit voltage applied. All fault-path conductors must be large enough to carry the required fault current without thermal damage to the conductor.

5.3.1 Clearing a Fault to the Frame of the Power Plant

(R) A reliable fault-clearing path is needed to clear a fault from the protected side of the –48V bus (hot bus) to the frame of the power plant. Two possible paths exist for this purpose, as described in the next two paragraphs.

5.3.1.1 Conductor B as Part of the Sole Fault-Clearing Path

(CR) As shown in Figure 5-4, one path is from the frame of the power plant to the CO GRD bus on the same floor (Conductor B), to the vertical equalizer, to the MGB, and back to the –48V return bus in the power plant via the 750 MCM conductor shown. This path can provide rapid and safe fault clearing if all of its conductors are sized to permit the desired fault current and to provide adequate current-carrying capability. If this path is to be used as the sole fault-clearing path, the entire path shall be verified to determine its adequacy. The minimum size of Conductor B shall be No. 1/0.

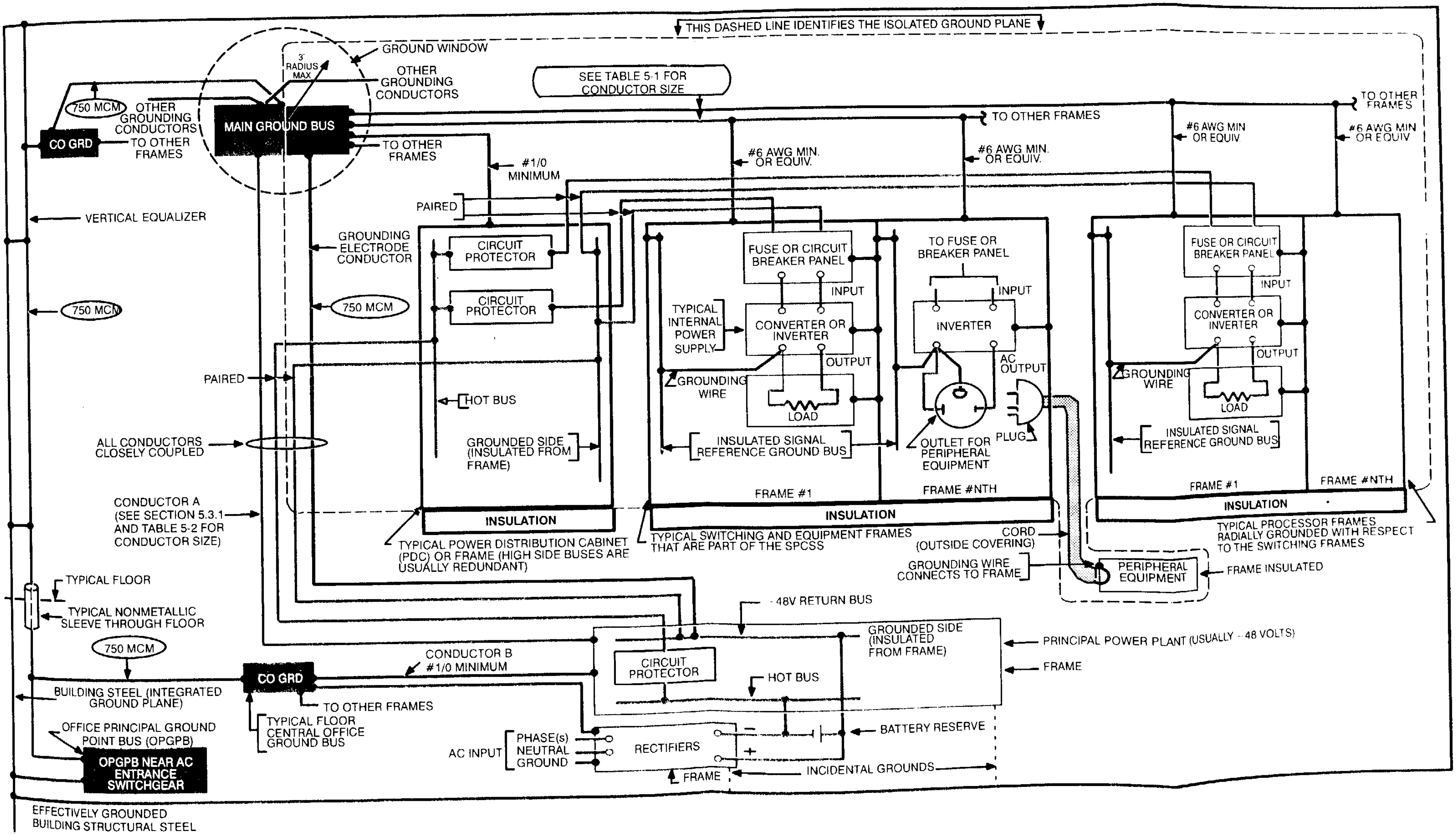


Figure 5-4. Typical Grounding and Power Feed from a Dedicated DC Power Plant Powering Isolated Ground Plane Loads

5.3.1.2 Conductor A as Part of the Sole Fault-Clearing Path

(CR) In the second case, the fault path is from the frame of the power plant to the MGB with Conductor A, and then back to the –48V return bus in the power plant using the 750 MCM conductor shown. This path, properly sized to enable the desired fault current and to provide adequate current-carrying capability, can also provide rapid and safe fault clearing as the sole fault-clearing path. Table 5-2 (Size 1) indicates minimum conductor sizes for Conductor A as a function of the power plant's largest overcurrent protective device rating and the length of Conductor A between the power plant frame and the MGB. The conductors (Size 1) shown in the table are based on fault-path resistances that enable ten times the rated current of the power plant overcurrent protective device. The table also includes minimum conductor sizes to preclude conductor thermal damage based on the melting characteristics of copper conductors. The conductor sizes shown in the table will enable relatively slow acting type-NON fuses to operate in approximately 1 second. Other types of fuses and magnetic circuit breakers may operate in even less time.

5.3.1.3 Conductor A as a Redundant Fault-Clearing Conductor

(CR) If the Conductor B fault-current path (via the vertical equalizer) is installed but its adequacy as a fault-clearing path cannot be confirmed, Conductor A may then be implemented as a redundant (supplemental) fault-path conductor using a less conservative design than that used when Conductor A is part of the sole fault-clearing path. With reference to Table 5-2, the Size 2 conductors are intended to be used when Conductor A is used to supplement the Conductor B fault path. The Size 2 conductors are smaller than the Size 1 conductors and, by themselves (without any resistance reduction from the parallel Conductor B path), will enable type-NON fuses to operate in 10 seconds.

5.3.1.4 Conductor A as a Coupled Bonding Conductor

(CR) In addition to its function as a fault-path conductor, Conductor A also serves as a coupled bonding conductor (CBC) to reduce the lightning-caused surge potential difference between the power plant frame and its enclosed components. In areas exposed to disturbances from lightning, Conductor A is required as a CBC with the following three exceptions: (1) Buildings that are unlikely to be struck by lightning because they are within the cone-of-protection of higher buildings; (2) Where the MGB and the power plant are located within one floor of each other, surge voltages will be too low to cause difficulty; (3) Where the powering cables are carried on cable racks that are bonded together and connected to the MGB and to the frame of the power plant, thereby serving the function of a CBC without need for a separate conductor.

Where Conductor A serves as part of the fault-clearing path, it also serves as a CBC. Where a CBC is required but Conductor A is not required for fault-clearing, then

Conductor A, sized in accordance with Table 5-2, Size 2, shall be installed for use as a CBC.

Table 5-2. Minimum Conductor A Sizes

Power Plant Protective Device Rating (Amperes)

Conductor Length (Feet) – Power Plant Frame to MGB	200 A	225 A	300 A	400 A	500 A	600 A
To - 50'	No. 4 / No. 6	No. 4 / No. 4	No. 3 / No. 4	No. 2 / No. 3	No. 1 / No. 2	No. 1/0 / No. 1
51 - 100'	No. 3 / No. 6	No. 2 / No. 4	No. 1 / No. 4	No. 1/0 / No. 3	No. 3/0 / No. 2	No. 4/0 / No. 1
101 - 150'	No. 1 / No. 6	No. 1/0 / No. 4	Nc. 2/0 / No. 4	No. 4/0 / No. 2	250 MCM / No. 1	300 MCM / No. 1/0
151 - 200'	No. 1/0 / No. 4	No. 2/0 / No. 4	No. 4/0 / No. 2	250 MCM / No. 1	350 MCM / No. 1/0	500 MCM / No. 3/0
201 - 250'	No. 3/0 / No. 4	No. 3/0 / No. 3	250 MCM / No. 1	350 MCM / No. 1/0	500 MCM / No. 3/0	750 MCM / No. 4/0

Size 1 / Size 2

Size 1 – Size of Conductor A When Part of the Sole Fault–Clearing Path

Size 2 – Size of Conductor A When Part of a Supplemental Fault–Clearing Path

5.3.1.5 Summary

(CR) Where the Conductor B path is intended for fault-clearing:

- Conductor B is minimum No. 1/0 (larger where determined to be necessary)
- Conductor A is deleted where not required for redundancy or as a CBC
- Conductor A is sized per Table 5-2, Size 2, where needed for redundancy or as a CBC.

Where the Conductor A path is intended as the sole fault-clearing path:

- Conductor A is sized per Table 5-2, Size 1 (the CBC function is also provided)
- Conductor B is No. 1/0.

5.3.2 Type

(R) All grounding conductors of No. 6 AWG or greater shall be made of stranded copper. AC grounding conductors shall be covered with green insulation and shall be listed for the purpose by a Nationally Recognized Testing Laboratory. DC grounding conductors shall be tagged with an appropriate grounding designation at each end.

(R) Aluminum wire shall not be used.

(R) Armored cable containing a bare bonding strip to decrease sheath resistance shall not be used as an equipment ground conductor. Armored cable can be used if a separate, green, insulated wire is enclosed in the armored sheath.

> **NOTE** – Armored cable should not be run in cable racks with other cables.

Exceptions to these rules are listed below:

a. Copper bus and braided-copper equivalents may be used instead of stranded copper to facilitate individual frame-to-frame grounding in an isolated ground plane.
b. Frame-to-frame grounding conductors may be bare.
c. In ac power feeds, if the phase and neutral conductors are made of aluminum, the associated insulated aluminum grounding conductor may be used where the conductors are installed in accordance with the listing requirements.
d. Buried ground rings employ solid conductors.

5.3.3 Connections

(R) Only two-hole crimp (compression) connectors listed for the purpose by a Nationally Recognized Testing Laboratory shall be used. Threaded pressure connectors shall not be used. Torquing and bolt assembly requirements (for securing the connector) shall be as specified by the connector supplier.

(R) Conductors shall be coated with an appropriate anti-oxidant compound before crimp connections are made. All unplated connectors, braided strap, and bus bars shall be brought to a bright finish and then coated with an anti-oxidant before they are connected. Tinned or silver-plated connectors and other connection surfaces do not have to be prepared in this manner. All raceway fittings shall be tightened to provide a permanent low impedance path. Multiple connectors shall not be secured by the same bolt assemblies except at bus bars.

5.3.4 Single Grounding Conductors

Single grounding conductors are grounding conductors that do **not** have associated phase (hot) or neutral (return) conductors. Examples of this type of conductor are vertical equalizers (illustrated in Figures 5-4 and 5-6) and the ac power grounding electrode conductor (illustrated in Figure A-1). Two important considerations in the routing of single grounding conductors are "girdling," as described in Section 5.3.4.1, and bending radius, as described in Section 5.3.4.2. Single grounding conductors should be surface-mounted to facilitate inspections. For example, they may be routed on and secured to separate cable racks or cable brackets. They may also be secured to the side or bottom of cable racks, to the side of auxiliary framing channels, or to other ironwork details other than conduit.

5.3.4.1 Girdling

"Girdling" refers to the encirclement of single grounding conductors by a ring of ferromagnetic metal. This occurs in these typical situations:

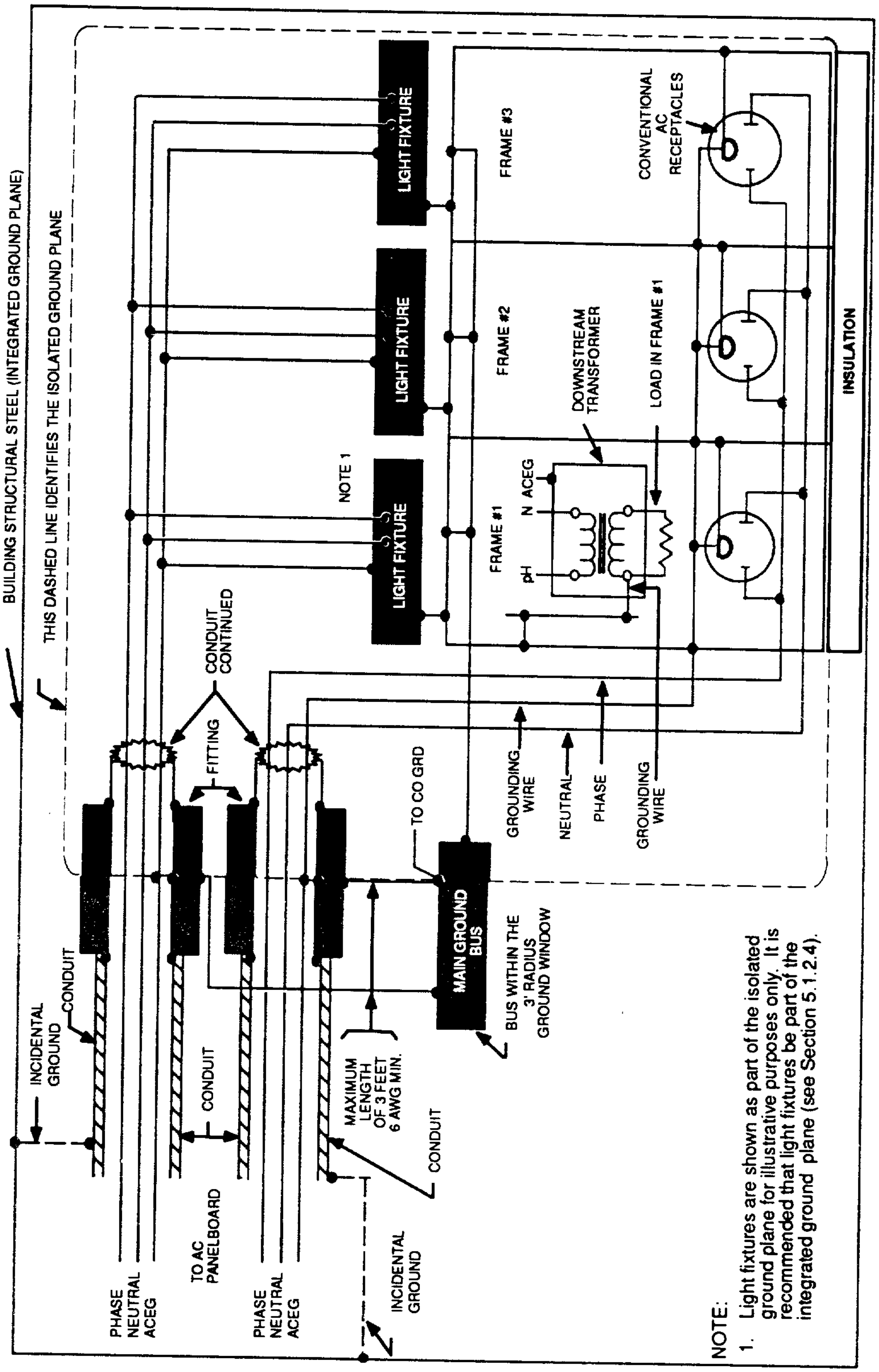
- Steel frames and cover plates used where conductors pass through holes in floors
- Steel cable-hole liners and conduit used where conductors pass through floors or walls
- Steel conduit used for physical protection of conductors
- Steel rings used for supporting conductors.

An induced voltage appears in conductors when they carry lightning surge currents. Ferromagnetic girdling contributes an additional (undesired) induced voltage. The previous issue of this document contained recommendations based on calculations that did not include the effects of eddy currents flowing in the girdling material. New calculations, which include this effect, indicate that the increased magnitude of the induced voltage is much less than previously thought. Experiments support this result. The revised recommendations pertaining to girdling are as follows:

- Steel frames (up to 6 inches high), and cover plates used at floor penetrations contribute negligibly to induced voltage and may be used without restriction.
- At locations where conductors pass through walls and floors, nonmetallic liners or conduits are preferred; however, steel liners and conduit in lengths up to 3 feet may be used where necessary, since their contribution to increased induced voltage is small. "End-bonds" between the conduit and the conductor achieve a modest reduction in induced voltage (a factor of about 0.5), and are recommended. Because of their larger diameter, liners contribute less induced voltage than conduit, so bonding to liners is not necessary.
- Other applications where longer runs of steel conduit (longer than 3 feet) enclose single grounding conductors should be avoided. Note that because end-bonding has only a modest effect, it is not an adequate mitigation method for the case of single grounding conductors that have been installed in steel conduit by mistake.
- Fully closed steel supporting rings may cause significant induced voltage when the rings are closely spaced (e.g., at 12-inch intervals), so steel rings should be avoided. "Gapping" a steel ring is helpful, depending on the size of the gap, but rings made of nonmagnetic material (conductive or not) are preferred. Steel J-hooks are an acceptable means of supporting single grounding conductors.

5.3.4.2 Bending Radius

(R) Single grounding conductors shall be routed in as straight a line as is practicable. Changes of direction shall be taken over as wide a radius as possible, with a minimum radius of 1 foot.



NOTE:
1. Light fixtures are shown as part of the isolated ground plane for illustrative purposes only. It is recommended that light fixtures be part of the integrated ground plane (see Section 5.1.2.4).

Figure 5-5. Typical AC Power Feed to an Isolated Ground Plane

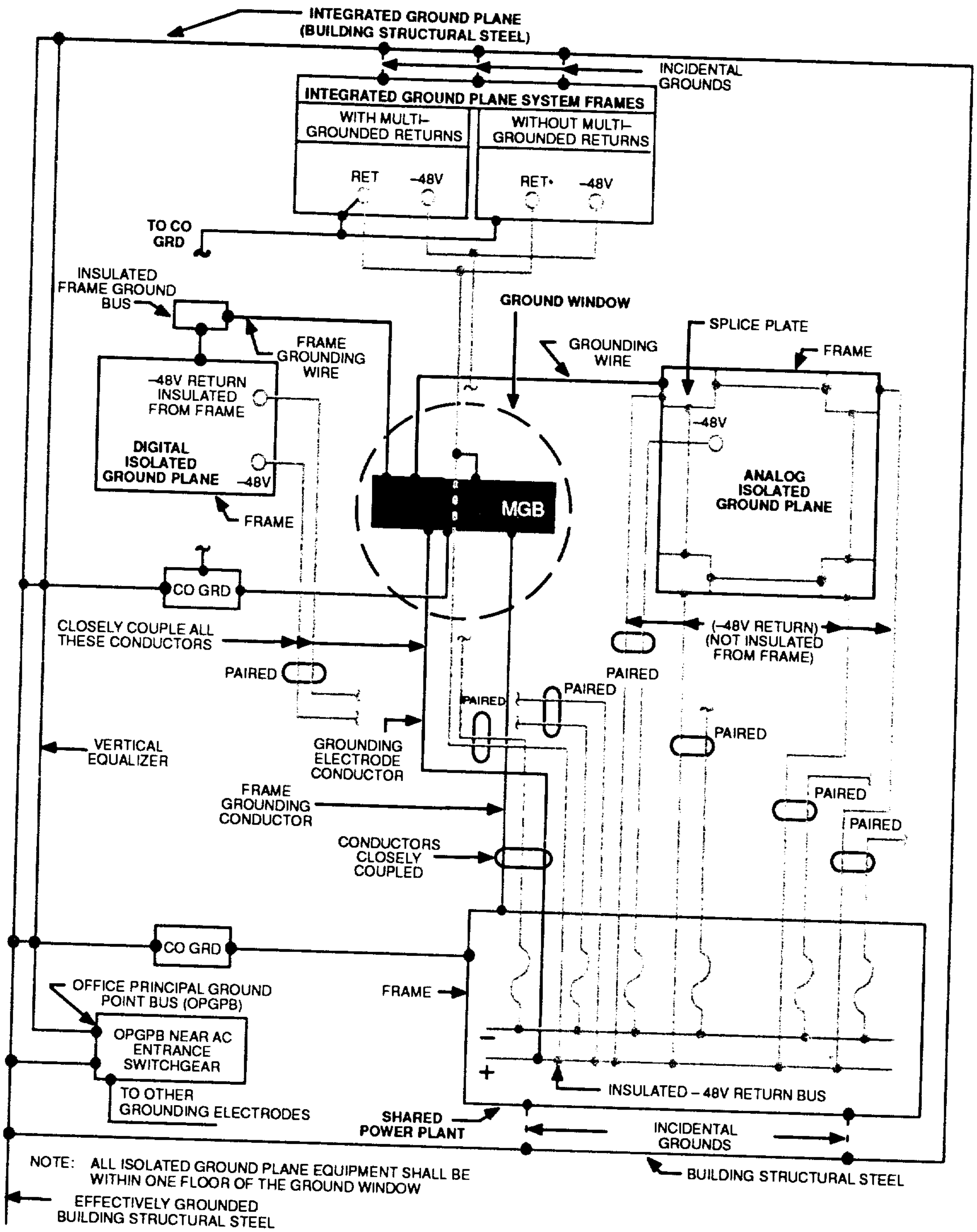


Figure 5-6. Typical Grounding for Integrated and Isolated Ground Planes Powered from a Common Power Plant

5.4 External Principal Power Plant Grounding Requirements

The principal power plant frame serving an isolated ground plane is not part of the isolated ground plane it serves.

> **NOTE** – Situations may arise where it is beneficial to place the power plant frame(s) in the isolated ground plane. In such arrangements, all requirements for isolated ground plane equipment must be applied to the power plant frame(s). The most notable of these would be the insulation of the framework from integrated ground plane members and the treatment of the ac raceways and equipment grounding conductors feeding the rectifiers in the isolated ground plane.

5.4.1 The Return Bus

(R) The return bus (usually the positive side of the system) in the power plant shall be insulated from the plant's frame.

> **NOTE** – The *return bus* referred to in this document is sometimes called the *–48 volt return bus*, the *battery return bus*, or the *ground return bus*. For an exception to this rule, refer to Section 5.10.2.2, *Requirements for Plants with a Noninsulated Return Bus*.

5.4.2 Grounding the Return Bus

(R) The return bus in the power plant shall be grounded at the MGB within the ground window with a conductor sized as indicated in Table 5-1.

5.4.3 Grounding the Plant's Frame

(R) For personnel safety, the plant's steel framework shall be grounded at the nearest ground reference, often the CO GRD located on the same floor.

(CR) Installation of an additional frame-grounding conductor may be required between the plant's framework and the MGB (see Section 5.3.1). This conductor, where required, shall follow the path of the plant's grounding electrode conductor (see Figures 5-4 and 5-6), and shall be sized as described in Section 5.3.1.

5.4.4 Location of the Power Plant

The location of the power plant with respect to the isolated ground plane is not restricted provided that the –48 volt return bus in the plant is NOT used as a ground window (see Section 5.10).

5.4.5 Power Feeders

(R) The power feeds from the principal power source shall be run in pairs to each PDC. The pairs shall be routed in proximity to the plant's grounding electrode conductor and frame grounding conductor. At the PDC, the "hot" conductor and the return conductor shall be insulated from the PDC frame. The return conductor in the pair should not be connected to the MGB.

NOTE – Some digital SPCSS suppliers choose to connect one or more battery return leads directly to the MGB, claiming more immunity from lightning disturbances that come from subscriber lines. (Bellcore treats this problem by requiring physical proximity of all these conductors. See above paragraph.)

Bellcore does not agree with this approach, because in shared power plant installations with additional digital, analog, toll, or electromechanical loads, and when the ground window is NOT the –48 volt return bus, the return conductors from these additional loads will be paralleled with the digital SPCSS return conductors when the ground window connection is made. This paralleling of –48 volt return conductors exposes the digital systems to electrical noise exchange. The noise exchange can occur daily due to normal operations (e.g., electromechanical relay switching) or on rare occasions when power crosses, direct lightning strokes, or power faults occur.

For these reasons, direct connections between the –48 volt return and the MGB should be made only when a dedicated power plant is used or when the –48 volt return bus in the power plant is used as the ground window.

5.5 Integrated Ground Plane Loads

5.5.1 Loads Fed from the Principal DC Source

(R) Integrated ground plane loads fed from the same principal dc power source that supplies the isolated ground plane loads shall be examined to determine if powering such loads multigrounds the return conductor.

If the return conductor is multigrounded at the distribution point or at the loads themselves, it shall then pass through the ground window and be bonded to the MGB before it is routed to the return bus within the power plant. The battery and return conductors should be paired to the greatest extent practicable between the power plant and the equipment being powered.

NOTE – Multigrounding occurs if the return conductors to these loads have not been insulated from the integrated ground plane frames along their entire length.

Examples:

1. A local power distribution bay in the integrated ground plane whose return bus is connected to its frame (BDFBs will normally be multigrounded)
2. Loads in the integrated ground plane that have a common return connected to the frame in which they are mounted
3. Wiring options in plugs and connectors that interconnect the case and the return conductor.

If the return conductor serving integrated ground plane loads is not multigrounded anywhere along its length, it shall not pass through the ground window or be connected to the MGB.

Example:

The input power feed to separately derived power supplies, such as 130 volt converters or 120-volt inverters whose output serves integrated ground plane loads.

5.5.2 Loads Fed from Internal Power Sources

(R) When integrated ground plane loads fed from power sources internal to the isolated ground plane multiground the return conductors, these return conductors shall be routed through and connected to the MGB within the ground window before they are connected to the power source return bus.

5.6 Frame Ground Reference Buses

(O) It is desirable that isolated ground plane frames containing separately derived ac and dc power sources (e.g., isolating transformers, inverters, and converters) be equipped with a grounding bus (or buses) that is referenced to the MGB via the frame-grounding conductors. These buses should have only a single connection to the frame.

5.6.1 Grounding Internal DC and AC Power Supplies Within the Isolated Ground Plane

(R) Separately derived ac and dc power supplies shall be single-point grounded by making a connection from the conductor on the output that is designated to be grounded to the nearest ground reference bus. This grounding conductor shall **not** be used to conduct normal load current. The grounding location shall be at the immediate output of the power supply. Loads should be powered with separate pairs of conductors, and the frames containing the loads shall be grounded.

When two or more power sources supply power to circuits that have a common return conductor, there shall be a single-point grounded reference. This shall be accomplished by making a single connection from the common return conductor to the nearest ground reference bus.

Exceptions: The above method of grounding internal power supplies is preferred because when short circuits occur, the associated transient disturbance is contained within the affected equipment, and the impedance of the short-circuit path is minimized. Despite these advantages, some suppliers prefer to ground the output of some of their power supplies in either of the following ways:

a. to the –48 volt return conductor directly or indirectly

b. by connecting a separate grounding conductor to the ground window.

When either of these methods is used, other circuitry in the digital switch experiences the transient disturbances because short-circuit current will flow on conductors outside the affected equipment. Also, the impedance of the short-circuit path will be increased. Therefore, grounding methods a and b may be used with the following conditions:

- Provide data that specifies the maximum impedance that can be in the external short-circuit path and still permit sufficient short-circuit current to flow so that overcurrent detectors can operate satisfactorily
- Provide test data that shows that when a short to a frame occurs, the transient disturbances generated do **not** interfere with the operation of other equipment.

THE GROUNDED CONDUCTOR OF THE INPUT POWER TO A SEPARATELY DERIVED SOURCE (e.g., THE AC NEUTRAL OR THE –48 VOLT RETURN LEAD) SHALL NOT BE CONNECTED TO ANY FRAME. THIS VIOLATES THE SINGLE-POINT GROUND OF THESE POWER SOURCES.

5.7 Grounding the External AC and DC Power Supplies Feeding Isolated Ground Plane Loads (other than the principal power source)

5.7.1 DC Power Supplies

(R) These power supplies shall be grounded in the same manner as the principal power source. That is, a separate grounding conductor (sized correctly as shown in Figure 5-3 and Table 5-1) shall be run from the grounded side of the supply's output to the ground window. Load conductors should be run in pairs and in proximity to their associated grounding conductor.

5.7.2 AC Power Supplies

(R) Circuit conductors from these power supplies (grounded at their source as described in Section 4.3.3) shall be routed through the ground window. Each equipment grounding conductor and raceway associated with each supply shall be connected to the MGB within the ground window with a conductor that is no longer than three feet. (These connections and wire sizes are shown in Figure 5-3 and Table 5-1.)

(R) All ac raceways running beyond the ground window toward the isolated ground plane shall be insulated from the integrated ground plane and from any incidental grounds. Where required, a separately derived dedicated ac power supply located and grounded at the ground window may be used.

5.7.2.1 Treatment of the AC Conductors

(R) The ac neutral shall **not** be connected to the MGB. Within the isolated ground plane, ac power conductors shall be run in separate metallic raceways that do not contain dc conductors.

5.8 Specific Examples of AC and DC Grounding Principles for Isolated Ground Planes

Figures 5-4 and 5-5 illustrate the ac and dc grounding requirements of this Technical Reference. The dashed line in each of the figures identifies the bounds of the isolated ground plane. The figures show the grounding of frames and power sources and indicate grounding-wire sizes. They also show ac and dc power distribution to the extent that it relates to meeting the grounding requirements. Power to loads that are **not** part of the isolated ground plane, such as lighting fixtures, are not shown.

> **NOTE –** Figure 5-5 shows lighting fixtures that are part of the isolated ground plane and general-purpose receptacles powered from an external ac source. It is preferred that lighting fixtures be part of the integrated ground plane (see Section 5.1.2.4) and that receptacles be powered from an internal ac source (see Section 4.3.3.7.1).

5.9 Grounding the Common Power Plant and Powering the Integrated and Isolated Ground Plane Systems

Figure 5-6 shows how dc power can be supplied to differently grounded switching or transmission systems from a common power plant with a separate ground window and still adhere to the grounding requirements for each of the systems.

5.9.1 Basic Requirements Applicable to All Systems

a. (R) The ground window and its MGB shall be within one floor of the most distant part of the isolated ground planes it serves. (There are no restrictions on the location of the ground window with respect to integrated ground planes.)

b. (R) The MGB shall be referenced to earth by connecting it to the nearest CO GRD or OPGP bus located on the same floor.

c. (R) All grounding conductors from external power supplies serving the isolated ground planes shall be routed through and connected to the MGB within the ground window. Grounding conductors serving the integrated ground plane need not be connected to the MGB.

   Examples of external power sources that have grounding conductors: 120-volt ac power for lighting and receptacles, and 130-volt dc power for coin return circuits.

d. The principal shared power plant can be located anywhere in the building if a portion of its return bus is not the MGB.

5.9.2 For Digital Isolated Ground Plane Switching Systems

a. (R) In these systems, the isolated ground plane and the power feed return conductors from external power supplies shall be insulated from each other in the switch.

b. (R) The isolated ground plane shall be grounded by connecting it to the MGB. Figure 5-6 shows this as a connection from the frame to an insulated frame ground bus and then to the MGB.

c. (R) All power feeds shall be run in pairs to the isolated ground plane power distribution centers. The pairs shall be closely coupled as far as practicable to the power plant's grounding conductor (all conductors in the same cable rack, and, where possible, the conductor insulation of the feeder pairs touching the conductor insulation of the grounding conductor). The return conductors should not be connected to the MGB.

5.9.3 For Integrated Ground Planes

Example: Electromechanical switching or radio transmission systems

(R) When the return conductors serving these systems are multigrounded (grounded at the load), all the conductors shall pass through the ground window and be connected to the MGB before they are run to the return bus within the power plant.

5.9.4 For Analog Isolated Ground Plane Switching Systems

(R) In these systems, the isolated ground plane shall be grounded by connecting it to the MGB within the ground window.

All power feeds of both polarities should be run in pairs to the isolated ground plane to provide close coupling, which keeps induced noise currents off of them. (It is not necessary to run each return conductor through the ground window and connect it to the MGB. However, if some systems require this, it is acceptable if the return conductor is paired with its "hot" mate.) In analog switching systems, the return conductor and the isolated ground plane are usually interconnected at the isolated ground plane; the battery return conductors and equipment metalwork are bonded together at many locations.

5.10 Ground Window Configurations

Three ground window plant configurations can be used with isolated ground planes:

a. A separate ground window

b. A ground window developed from a power plant that has an insulated return bus

c. A ground window developed from a power plant that does NOT have an insulated return bus.

5.10.1 Separate Ground Window

Requirements for this ground window configuration are covered in Section 5.2 and illustrated in Figure 5-4.

5.10.2 Using the Return Bus as the Ground Window

For some installations it is practical to use a portion of the principal power plant's return bus as the ground window serving an isolated ground plane. Figures 5-7 and 5-8, respectively, show typical arrangements for insulated and noninsulated return bus plants.

> **NOTE** – Connections of return conductors for isolated ground plane loads are not considered to be located within the ground window.

Three advantages can be realized:

a. A plant that has a return bus connected to its frame can be used.

b. The return conductors that provide power to integrated ground plane loads from a shared power plant can be run directly to the return bus because the return bus has become the ground window.

c. The voltage stress that can build up between the return bus and the plant's frame is minimized when lightning or other fault currents flow in the building.

(R) The plant shall be located within one floor of the isolated ground plane(s) it is powering, although location on the same floor is preferred. Integrated ground plane loads powered from the same power plant have no restrictions on their location.

5.10.2.1 Requirements for Plants with an Insulated Return Bus (see Figure 5-7)

(R) All grounding conductors and return conductors that can conduct lightning or fault currents shall be grouped together along one section of the bus and in the sequence shown in Figure 5-7. This bus section is the ground window; it should be as short as practicable but in no case longer than 6 feet. Figure 5-7 identifies these conductors with an asterisk.

The return conductors that serve loads in the isolated ground plane should be grouped along the end of the bus where **no** lightning or short circuit currents can flow. (In Figure 5-7, this section is at the bottom part of the return bus.)

5.10.2.2 Requirements for Plants with a Noninsulated Return Bus (See Figure 5-8)

(R) Lightning and short-circuit currents can flow along the entire length of the noninsulated return bus because the bus is connected to the plant's frame. Consequently, if the return conductors serving the isolated ground plane loads were connected to this bus, undesired voltage differences between these conductors could be produced when these currents flow.

One way to prevent this is to add an insulated auxiliary bus to the plant and then, at a single point, connect it to the multigrounded bus as shown in Figure 5-8. This new arrangement is equivalent to an insulated bus plant, because now the return conductors serving the isolated ground plane loads can be connected to the insulated bus section on which no lightning currents can flow.

> **NOTE** – The single point connection between the insulated and noninsulated bus should be implemented with a bus assembly that has sufficient current-carrying capacity. If the bus assembly is impractical for some installations, paralleled conductors of equal ampacity and length assembled with abutting connectors are acceptable.

The sequence of conductor connections to the noninsulated and the insulated return buses is the same as described for an insulated plant.

5.11 Methodology

(R) The procedures listed below shall be followed to meet the requirements and objectives of this Technical Reference:

a. Install and assemble the isolated ground plane frames as a single conductive unit.
b. Test the insulation resistance between the installed frame assemblies and the building integrated ground plane before making any external connections. Resistance shall be 100,000 ohms or more with 500 volts dc applied.

c. Establish a ground window within one floor of the isolated ground plane.

d. Make all required connections to the MGB within the ground window that involve grounding of external power supplies, grounding of frames, connections to certain return conductors, and connections to ac power grounding wires.

e. Run paired power leads from the principal power plant to each PDC (or equivalent) in the isolated ground plane that are closely coupled to the plant's frame and system grounding conductors. Do not connect return conductors to the MGB.

f. Run other required external sources of power to the isolated ground plane to meet the requirement that the grounding wire associated with each of these sources shall be routed through the ground window and connected to the MGB.

g. Ground the output of all internal power supplies and frames as required.

h. Connect peripheral equipment to the isolated ground plane as required.

i. Run required prepower tests.

j. When all these conditions have been satisfied, power up the equipment.

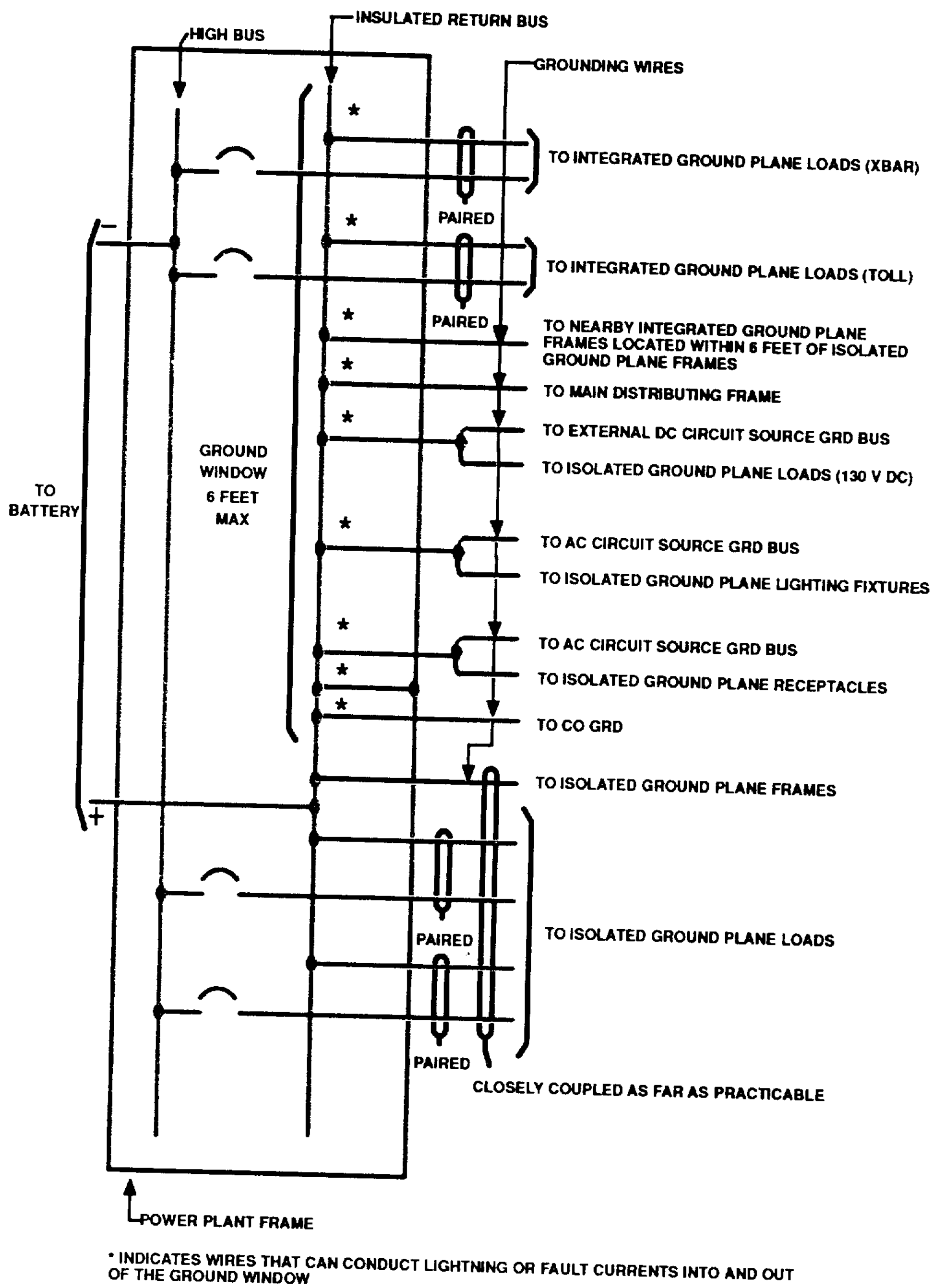
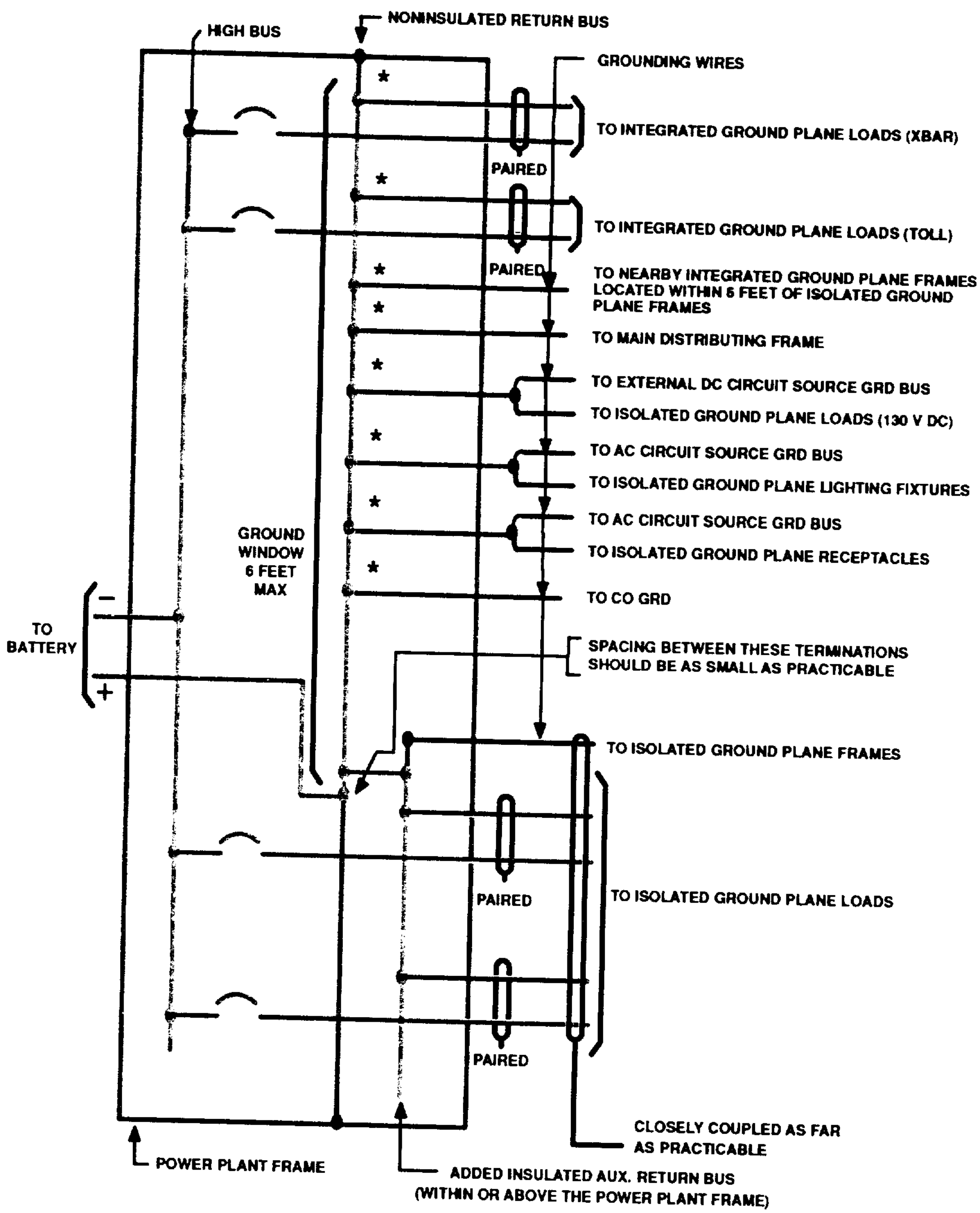


Figure 5-7. Using an Insulated Return Bus as the Ground Window



* INDICATES WIRES THAT CAN CONDUCT LIGHTNING OR FAULT CURRENTS INTO AND OUT OF THE GROUND WINDOW

Figure 5-8. Using a Noninsulated Return Bus as the Ground Window

6. Performance Verification and Test Procedures

NOTE – (R) All instrumentation used in the tests described in this section shall have a readout accuracy within a tolerance of plus or minus 5 percent.

6.1 Visual Tests

Visually inspect the isolated ground plane for observable violations such as loose connections, improper conductor size, and improper or poor connections.

6.1.1 Spotting Isolated Ground Plane Violations

a. (R) Conduits and cable racks that have become part of the isolated ground plane by being routed through the ground window and connected to the MGB shall not be in contact with any other elements of the integrated ground plane.

b. (R) Peripheral equipment frames that are part of the isolated ground plane shall not be in contact with any elements of the integrated ground plane.

c. (R) Peripheral equipment that is part of the isolated ground plane shall be powered from sources within the isolated ground plane.

d. Test equipment powered from ac outlets NOT installed on the isolated ground plane can cause a violation of the isolated ground plane through the ACEG conductor.

6.1.2 Grounding of Power Supplies

(R) Internal and external power supplies shall be checked to see that they are grounded as required.

6.2 External Power Supplies

a. (R) All dc power supplies shall be grounded at the MGB within the ground window.

b. (R) All separately derived ac power supplies shall be grounded at their immediate output.

6.3 Internal Supplies

(R) All internal power supplies shall be grounded at the signal reference bus (see exceptions in Section 5.6.1).

6.3.1 Ground Window Conductors

(R) All required conductors that are connected to the MGB within the ground window shall be checked (see Figure 5-3 and Table 5-1 for a checklist). Check for the following: conductor size, two-hole crimp connectors, tightness of connections, that the wire is stranded copper, and the condition of the connecting surface.

6.3.2 Listing Label and Wiring

(R) Each ac power system component in the isolated ground plane shall be checked to ensure that it is listed by a Nationally Recognized Testing Laboratory, labeled, and that the wiring is in accordance with the NEC.[1]

6.3.3 Power Feeds

(R) A check shall be made to determine that the power feeds are properly paired and that the return conductor is not connected to the MGB within the ground window.

6.3.4 Continuity Tests

(R) Check all raceway fittings and frame parts for continuity. Insulated fittings in raceways and painted connection surfaces shall not be permitted.

6.4 Insulation Tests

(R) Each frame (or group of frames) that is part of the isolated ground plane shall undergo the following insulation tests after being secured to the floor. This shall be done before connecting any power or grounding conductors to the isolated ground plane. These tests ensure that the necessary insulation has been provided between the hold-down fasteners and the integrated ground plane.

6.4.1 Low-Voltage Resistance Test

(R) Connect an analog, universal, low-voltage ohmmeter between each frame (or group of frames) and the MGB within the designated ground window. Measure the resistance. The resistance reading shall be 100,000 ohms or more.

6.4.2 High-Voltage Resistance Test

(R) If the frames pass the low-voltage resistance test, connect a 500-volt megohmmeter between the lower part of each frame (or group of frames) and the MGB within the designated ground window to measure the resistance. The resistance shall be 100,000 ohms or more.

Test the lower part of the frame instead of the upper part to prevent equipment damage if the insulation breaks down.

6.5 Short-Circuit Tests

NOTE – The short-circuit tests that follow are intended to be performed only on out-of-service switching systems. The tests are typically performed as part of a switching system technical analysis.

6.5.1 DC Circuits

(R) At least one sample short-circuit test shall be performed on each type and size of dc power source associated with the isolated ground plane. Typical types of dc supplies are rectifiers, rectifiers with floating battery, and dc-to-dc converters. The main objective of these tests is to verify that such supplies are solidly grounded and that their protective devices (fuses or circuit breakers) operate in 0.1 second or less. A second objective is to observe how these shorts interfere (if they do at all) with the operation of the digital switching system. Shorts between the "hot" side of the source and return conductor and between the "hot" side of the source and the frame shall be initiated.

6.5.2 AC Circuits

(R) A sample short-circuit test shall be performed on each type of ac supply associated with the isolated ground plane, including commercial ac power for lighting fixtures and ac receptacles in the isolated ground plane. The test determines whether adequate short-circuit current is available to safely operate a protective device and whether the interrupting capacity rating of the protective device is adequate. An additional test objective is to determine if the short-circuit tests interfere with the operation of the switching system. The short circuit shall be caused from phase to phase (if two or more phases are present), phase to neutral, phase-to-ACEG, and phase to grounded frame. Supplies typically tested are dc-to-ac inverters, isolating transformers, and commercial ac power. Suggested test locations are at the dedicated and general-purpose receptacles farthest from the source. For power supplies having output ratings of 500 VA or less, a fuse or circuit breaker shall operate to clear the fault in 0.5 second or less. For commercial ac power, and for power supplies having output ratings greater than 500 VA, a fuse or circuit breaker shall operate to clear the fault in about 0.1 second.

6.6 Isolated Ground Plane Noise Current Tests

6.6.1 Abnormal Current Flow in Grounding Wires and Frames

While the telecommunications system is up and operating, clamp-on ammeters that can detect ac and dc current flow (in the range of milliamperes to amperes) may be used to search for and help eliminate noise currents in grounding wires and reference buses.

Under practical conditions, some circuit arrangements can cause current to flow in these conductors. Tests can identify the amount of current flow on the ground paths and, if necessary, remedial circuit arrangements can be made.

6.6.2 Correctly Wired Circuit Arrangements

(O) To meet Federal Communications Commission (FCC), Electromagnetic Interference (EMI), and Radio Frequency Interference (RFI) requirements, various types of filters (from feed-through capacitors to complicated pi-connected types) are used. All or part of each filter is often connected from the line to a frame, completing a circuit that causes current to flow in the frames. To avoid such currents, it is desirable to connect these devices from line to return conductor rather than from line to frame.

(O) If portions of the filter still must be connected from line to frame to meet FCC requirements, it is desirable that the shunting device to the frame be closely inspected to determine the highest impedance it can have while still performing the filtering functions.

(R) In any case, no single filter shall inject more than 3.5 milliamperes (ac or dc) into the frame.

6.6.3 Correcting Incorrectly Wired Circuit Arrangements

(R) The following circuit arrangements shall not exist within the isolated ground plane.

6.6.3.1 Multigrounded AC and DC Power Sources

This test concerns downstream interconnections between the ac neutral and the ACEG, or between the –48 volt return and the equipment frame.

Test to determine if these sources are multigrounded by making a low-voltage measurement on an operating circuit between the return conductor of the source and a nearby frame downstream from the point at which the power source has been properly grounded. If the voltage measured is less than one-tenth of a volt, multigrounding exists. If the voltage measured is greater than a tenth of a volt, no multigrounding exists.

This test should be performed at the following locations:

For AC Circuits:

a. At selected general-purpose receptacles on the frames

b. At the ac input to lighting fixtures that are part of the isolated ground plane.

For DC Circuits:

a. At the PDC

b. At the input to a converter

c. At the input to an inverter

d. At connector wiring that permits connecting a strap between the –48 volt return conductor and the frame ground.

6.6.3.2 Overvoltage Protectors

(R) Overvoltage protectors shall be connected from the line to the return conductor(s). When an overvoltage protector is incorrectly connected from line to frame, current is injected into the isolated ground plane. Therefore, the line to frame connection shall not be used.

In cases where downstream circuit insulation could be stressed by overvoltage conditions that appear between the return conductor and the frame, an additional protector should be connected from the return conductor to the frame. Thus, with two protectors connected, one from line-to-return and the other from return to frame, no current is injected into the isolated ground plane.

6.6.3.3 Improper Load Connections

(R) Loads that are wired between line and ground (rather than between line and return conductor) inject large amounts of current into the isolated ground plane. This type of load wiring shall not be used.

(O) When more than one ampere of either ac or dc current is found flowing in any of the grounding wires, it is an objective that the above circuit violations be located and corrected.

Appendix: Overview of Central Office Bonding and Grounding Methods

This Appendix provides a brief overview of the bonding and grounding methods used in a typical telephone central office building and shows how the isolated ground plane fits into the total bonding and grounding plan for the building.

1. Install an Office Principal Ground Point Bus (OPGPB) near but outside the ac entrance switchgear enclosure. (See Figure A-1.) Bond the OPGPB to the frame of the switchgear enclosure and to the grounding electrode conductor for the electrical service. Connect the main grounding and bonding conductors and all grounding electrodes to the OPGPB as shown in Figure A-1.

   In the past, the grounding electrode often was the metallic underground water pipe serving the building. Increased use of insulating couplings and nonmetallic water pipes in water systems now makes water pipes, at worst, unreliable as grounding electrodes and, at best, supplementary grounding electrodes. A suitable grounding electrode is now required as a substitute for the water pipe. Suitable grounding electrodes are:

   a. Ground rings or grids

   b. Ground rods or ground rod arrays

   c. Structural steel ground grids

   d. Well casings

   e. Any combination of the above.

Exception: In areas where the BCC has complete present and future control over the water piping on its property, and where the pipe is electrically continuous in the earth for at least 40 feet, it still can be used as an effective grounding electrode. However, the NEC[1] requires that a metal underground water pipe electrode be supplemented by an additional electrode (see NEC Section 250–81[a]).

NOTE – When a water pipe serves a central-office building and does not meet the requirements of the exception, it should be classified as a supplementary electrode and shall be bonded to other grounding electrodes making up the office grounding electrode system.

2. Install a vertical equalizer in a multistory building to establish a low-impedance connection to the OPGPB. On each floor, connect a central-office ground bus (CO GRD) to the vertical equalizer to form an effective earth reference. The distance between the vertical equalizer and the CO GRD bus shall be 20 conductor feet or less. In a single-story building, the OPGPB may be used as the CO GRD bus.

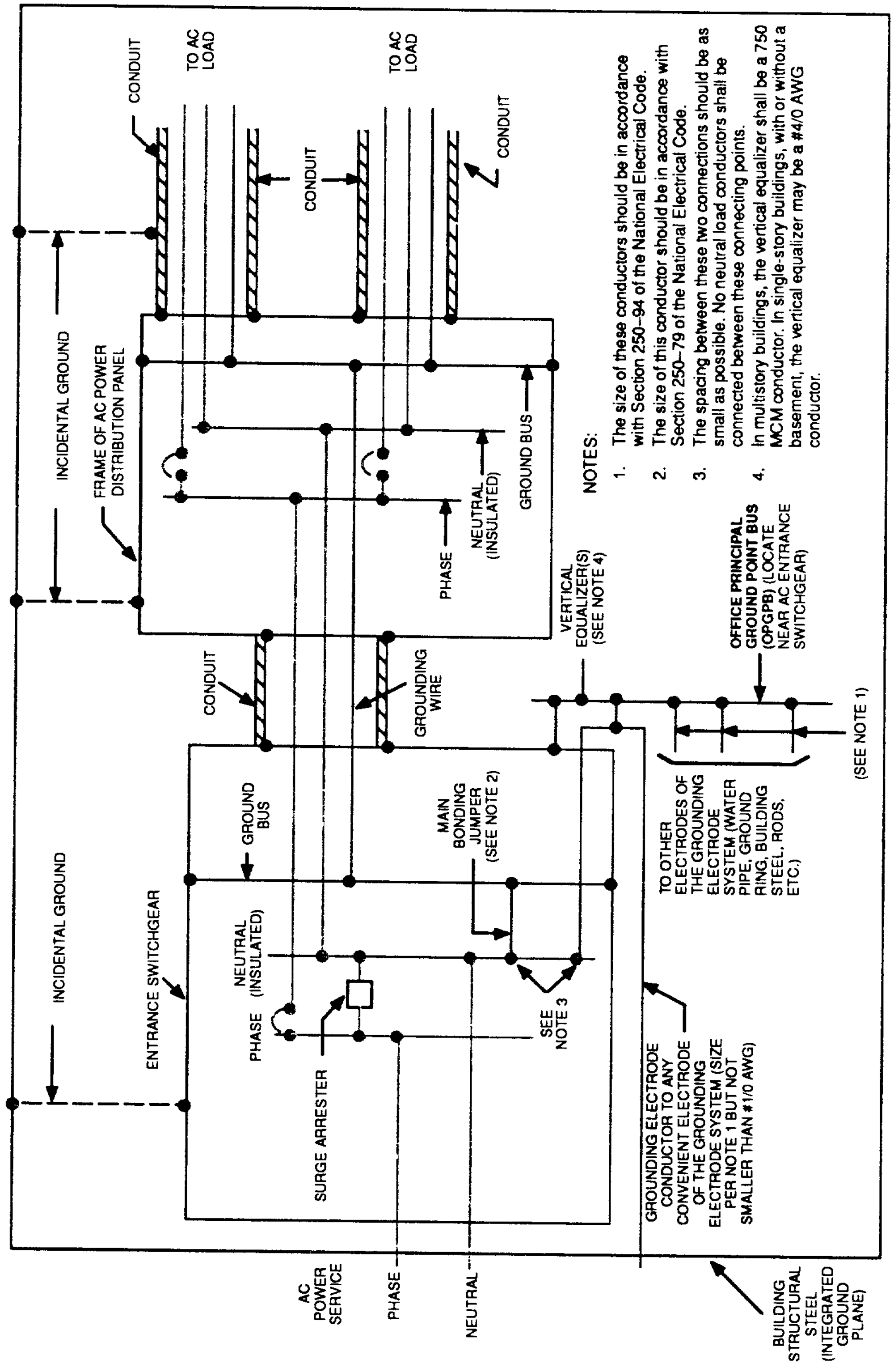


Figure A-1. Typical Power Service Entrance, Distribution, and Grounding

3. Determine the ground window location and the configuration to be implemented (see Section 5.10). Install the main ground bus (MGB) within the ground window.

4. Install the SPCSS and its associated processor as an isolated ground plane initially insulated from the building integrated ground plane. (See Figure A-2.) Then make a connection from the equipment frames to the MGB. (See Section 5.1.4 for options on the grounding of frames within an isolated ground plane.) Connect the MGB to the CO GRD bus on the same floor, completing the required connections.

5. Bond together the telephone cable shields that enter the building and connect them to the ground bus on the main distributing frame (MDF). If the MDF and the MGB are on the same floor, bond the ground bus on the MDF to both the CO GRD and the MGB.

6. Multiground the main distributing frame (treat it as an integrated ground plane) for personnel safety. Generally, it is bonded to the cable shields, building structural steel, CO GRD, and the MGB.

7. Treat radio toll equipment as an integrated ground plane. Bond its frames to the nearest ground reference. Depending upon each office layout, the nearest ground reference could be the CO GRD, the OPGPB, or building structural steel.

   NOTE – All grounding or grounded conductors associated with radio gear that can conduct lightning currents (including shields and the outer conductors of coaxial cables) should be kept as far away as possible, but no less than 3 feet from the isolated ground plane (see Section 4.5.1).

8. Route all external grounding wires that enter and serve the isolated ground plane through the ground window and bond them to the MGB. Then, connect them to the isolated ground plane.

   NOTE – For ease of identification, it is suggested that all grounding conductors and metal electrical conduits between the MGB and the isolated ground plane be appropriately designated or color-coded.

9. Connect the SPCSS and processor frames to the integrated ground plane through the ground window only. All metallic objects such as conduit, cable racks, armored cable sheaths, and grounding wires associated with these frames become a part of the isolated ground plane. Therefore, insulate them from the integrated ground plane once they have passed through and been bonded to the MGB within the ground window.

10. The grounding and bonding conductors in Figure A-1 provide return current paths that permit the operation of overcurrent protection devices (fuses and circuit breakers) when short circuits occur between dc "hot" leads and the frames. They do not normally carry load current.

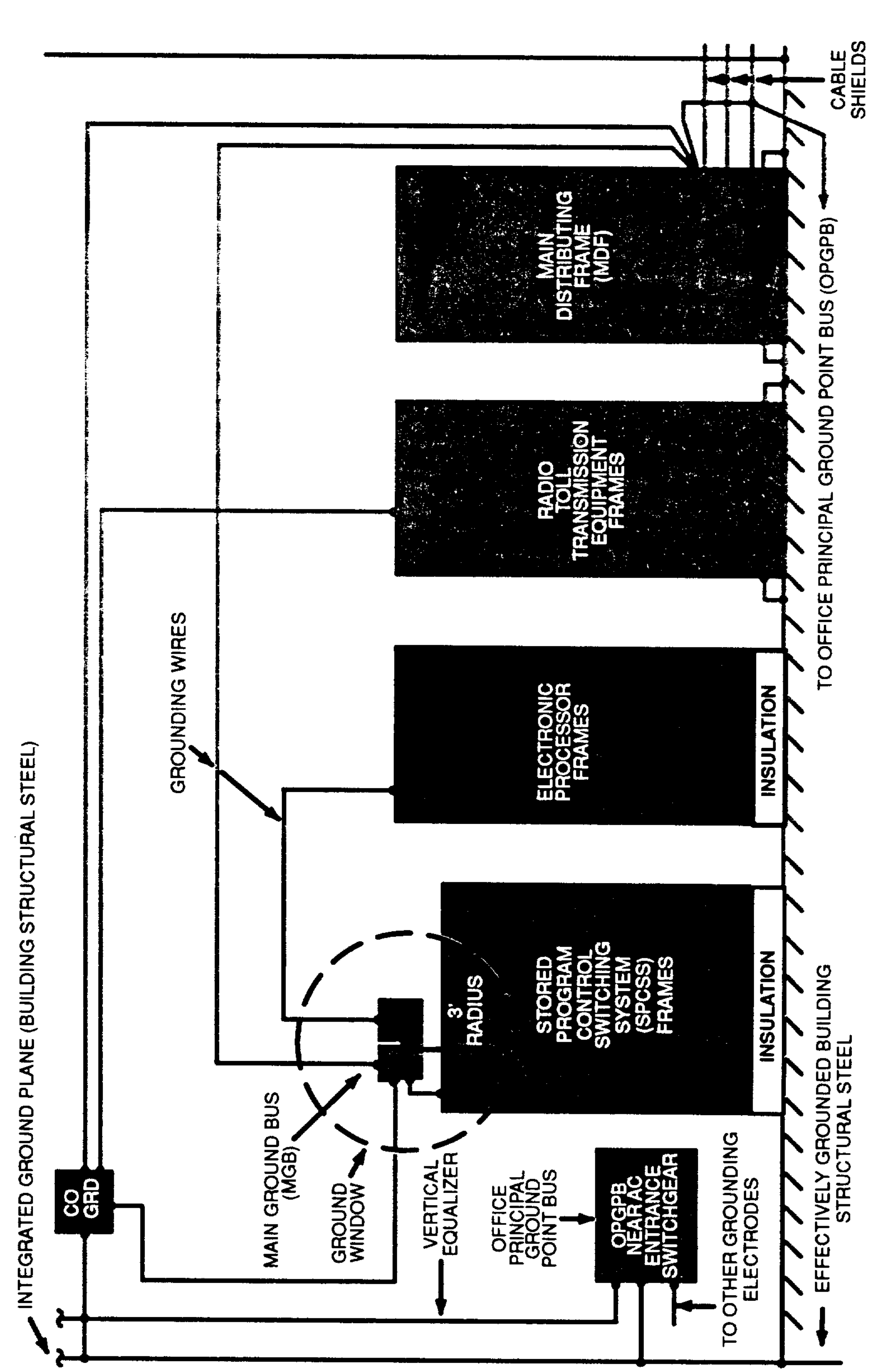


Figure A-2. Typical Overall Frame-Grounding Methods

References

[1] ANSI/NFPA 70, *National Electrical Code (NEC), 1990*

[2] CCITT, International Telegraph and Telephone Consultative Committee, Recommendation K.27, *Bonding Configurations and Earthing Inside a Telecommunications Building*

[3] TR-NWT-001089, *Electromagnetic Compatibility and Electrical Safety Generic Criteria for Network Telecommunications Equipment*, Issue 1, October 1991.

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