

# Radio Station Protection Engineering Considerations

## Contents

Subject	Page
<b>1. General</b> .....	<b>4</b>
1.1 Purpose .....	4
1.2 Filing instructions and Supersedures .....	5
1.3 Reason for Reissuing .....	5
1.4 Responsibility .....	5
1.5 Disclaimer .....	5
<b>2. Overview</b> .....	<b>5</b>
2.1 Scope .....	5
2.2 Definitions .....	6
2.3 References.. .....	9
2.4 Form .....	11
<b>3. Planning Ahead</b> .....	<b>11</b>
3.1 General .....	11
3.2 Predicting Lightning Incidence .....	11
3.3 Rural Areas .....	11
3.4 Locations to Avoid .....	12
<b>4. Site Construction and Design Considerations</b> .....	<b>12</b>
4.1 Building Types .....	12
4.2 Building Construction .....	12
4.3 Site Inspections .....	13
4.4 FuelTanks .....	13
<b>5. Electrical Protection Considerations</b> .....	<b>14</b>
5.1 General .....	14
5.2 Protection Elements .....	14
5.3 Common Bonding .....	14
5.4 Common Grounding. ....	<b>14</b>
5.5 Grounding System .....	15
5.6 Grounding Connection .....	15
5.7 Shielding .....	15
<b>6. Material Requirements</b> .....	<b>15</b>
6.1 Materials .....	15
6.2 Nationally Recognized Testing Laboratory (NRTL) Listing .....	15
6.3 Substitutions .....	15
6.4 Ground Rod Specifications .....	16
6.5 Connections .....	16

(continued)

Subject	Page
<b>7. Grounding Conductors</b> .....	<b>16</b>
7.1 Conductor Inductance .....	16
7.2 Conductor Requirements .....	17
7.3 Grounding Conductor Requirements .....	18
7.4 Ground Wire Physical Protection .....	18
7.5 Lead Designations .....	18
<b>8. Grounding System</b> .....	<b>19</b>
8.1 Attributes .....	19
8.2 Purpose .....	19
8.3 Improper Grounding .....	19
8.4 Components .....	19
8.5 Typical Site Arrangement .....	20
8.6 Leased Sites .....	20
<b>9. Site Grounding Electrode</b> .....	<b>21</b>
9.1 Design .....	21
9.2 Recommended Ground Resistance Objectives .....	21
9.3 Inability to Meet Objectives .....	21
9.4 Ground Electrodes .....	22
9.5 Ground Ring .....	22
9.6 Minimum Made Electrode .....	22
9.7 Placing Ground Rods .....	22
9.8 Supplemental Electrodes .....	23
9.9 Providing Access to Connections .....	23
9.10 Radial Grounding Conductors .....	24
9.11 Ground Rings.. .....	24
9.12 Fences .....	25
<b>10. AC Power Grounding Electrode</b> .....	<b>25</b>
10.1 Power Service Ground .....	25
<b>11. Antennas and Transmission Lines</b> .....	<b>25</b>
11.1 General .....	25
11.2 Antenna Grounding .....	25
11.3 Antenna Type .....	25
11.3.1 Parabolic Antennas .....	26
11.3.2 VHF/UHF Antennas .....	26
11.4 Coaxial Transmission Lines .....	27
<b>12. Antenna Support Structures</b> .....	<b>28</b>
12.1 General .....	28
12.2 Antenna Locations .....	28
12.3 Types of Support Structures .....	28
12.3.1 Guyed Metallic Towers .....	28
12.3.2 Self-Supporting Metallic Towers .....	28
12.3.3 Wooden Structures (Poles) .....	28
12.4 Guyed Towers .....	29
12.5 Self-Supporting Tower Footings .....	30
12.6 Sites with Wood Poles .....	30
12.7 Roof-Mounted Towers .....	31
12.8 Down Conductors .....	32
12.9 Roof Conductors .....	32
12.10 Antenna Support Protection .....	33
12.11 Grounding Requirements of Temporary Towers .....	34
12.11.1 Short Time Usage.....	34
12.11.2 Extended Temporary Use .....	34

(continued)

Subject	Page
<b>13. AC Power Service Protection</b> .....	<b>34</b>
13.1 General .....	34
13.2 Service Arresters .....	34
13.3 Isolation Gap .....	35
13.4 Bonding to Power .....	36
13.5 Branch Circuit Arresters. ....	36
13.6 Leased Site .....	36
13.7 Reference .....	36
<b>14. Transmission Lines</b> .....	<b>37</b>
14.1 General .....	37
14.2 Coaxial Transmission Line Grounding .....	37
14.3 Bulkhead Grounding .....	37
14.4 Radio Frequency (RF) Surge Suppressors .....	37
<b>15. Radio Station Equipment</b> .....	<b>38</b>
15.1 General .....	38
15.2 Interior Ring Bus System .....	38
15.3 Bonding to the Halo Ring .....	39
15.4 Items to be Bonded to the Halo Ring .....	39
15.5 Bending Radius of the Halo Ring .....	40
15.6 Master Ground Bar (MGB) .....	40
15.7 Colocated Sites Guidelines .....	40
15.8 Internal (Halo) Ground Rings and Colocation .....	40
15.9 Grounding Radio Equipment .....	41
15.10 Isolated Ground Zone (IGZ) Integrity .....	41
15.11 Leased Sites .....	41
15.12 Reference .....	41
<b>16. Global Positioning System (GPS)</b> .....	<b>41</b>
16.1 General .....	41
16.2 GPS Antenna .....	41
16.3 GPS Antenna Grounding .....	41
16.4 Lightning Arrester. ....	42
<b>17. OSP Entrance Facilities</b> .....	<b>42</b>
17.1 General .....	42
17.2 Telephone Facilities .....	42
17.3 Cable Shields .....	43
17.4 Telephone Service Protection .....	43
17.5 Protection.. ....	43
17.6 Cable Shield Voltages .....	43
17.7 Entrance Cable .....	44
17.7.1 Aerial Cable Entrance .....	44
17.7.2 Buried Cable Entrance .....	44
17.8 Other Circuits.. ....	44
17.9 Insulating Joints .....	44
17.10 Radio Frequency (RF) Shielding .....	45
17.11 Wire Facilities .....	45
<b>18. Lightning Considerations.</b> .....	<b>45</b>
18.1 General .....	45
18.2 Probability of Lightning .....	45
18.3 Lead 25 .....	45
18.4 Lead 26 .....	45
18.5 Lightning Protection .....	45

(continued)

Subject	Page
<b>19. Inspections</b> .....	<b>46</b>
19.1 Reference .....	46
19.2 Warning Tags .....	46
19.3 Identification Tags .....	46
19.4 Reports .....	46
<b>Exhibits</b>	
Exhibit 1 - Radio Station Grounding Floor Plan .....	47
Exhibit 2 - Radio Station Grounding Typical Wall Section .....	48
Exhibit 3 - Radio Station Grounding Self-Supporting Tower Plan .....	49
Exhibit 4 - Radio Station Grounding Self-Supporting Tower Footing Detail .....	50
Exhibit 5 - Guyed Tower Guy Anchor Detail .....	51
Exhibit 6 - Standard Grounding Arrangement - Typical Pole-Mounted Installation .....	52
Exhibit 7 - Antenna Grounding Details for Pole-Mounted Installation Sizes	53
Exhibit 8 - Standard Lead Designations and Grounding Conductor Sizes .....	54
Exhibit 9 - Standard Grounding Arrangement - Typical Large Microwave Repeater Building .....	59
Exhibit 10 - 120V/240V AC, One Phase, Three-Wire, Grounded Neutral Service .....	60
Exhibit 11 - 120V/240V AC, Three Phase, Four-Wire, Center Tap in One Phase, Delta Service .....	60
Exhibit 12 - 240V AC, Three Phase, Three-Wire, Corner Grounded Delta Service .....	61
Exhibit 13 - 120V/208V AC, Three Phase, Four-Wire, Grounded Wye Service .....	61
Exhibit 14 - Standard Internal Grounding Arrangement - Typical Fixed Radio Station Building .....	62
Exhibit 15 - Lead #22 Lightning Protection System .....	63
Exhibit 16 - Lead #22 Roof Tower .....	64
Exhibit 17 - Lead #25 Connection of Lightning Protection System .....	65
Exhibit 18 - Lead #26 Bonding of Metal Objects .....	66
Exhibit 19 - Lead #21 Interior Radio Ground Ring Connection .....	67
Exhibit 20 - Typical LORAN-C Antenna Grounding Scheme .....	67
Exhibit 21 - Typical GPS Antenna Grounding Scheme .....	68

## 1. General

### 1.1 Purpose

This practice provides engineering methods recommended for the grounding and electrical protection of radio stations and microwave relay stations, including antenna towers and the building grounding systems.

Use this information to protect:

- Personnel.
- Radio Station building(s).
- Radio Station (site) equipment including:
  - Antennas and supporting structures (towers).
  - Transmission lines.
  - Radio or carrier equipment.

# 1. General, continued

---

- 1.2 Filing Instructions and Supersedures** Discard all previous issues and associated addenda of this practice and file this issue numerically in your GTE Telephone Operations practices set.
- This practice supersedes and cancels:
- All policies, procedures, general instructions, letters, and memoranda which address this subject.
  - Any document which provides information contrary to the information contained in this practice.
- 1.3 Reason for Reissuing** This practice has been reissued to incorporate multiple changes in the content. Read this entire practice to ensure your familiarity with the new information.
- 1.4 Responsibility** This practice was published by the GTE Telephone Operations Enterprise Services Department. For more information about this practice, contact the GTE Telephone Operations Headquarters Protection Engineering Support Department.
- 1.5 Disclaimer** This practice was prepared solely for the use of GTE Telephone Operations. It must be used only by its employees, customers, and end users when installing, operating, maintaining, and repairing GTE Telephone Operations' equipment, facilities, and services. Any other use of this practice is forbidden. The information contained in this practice may not be applicable in all circumstances and is subject to change without notice. By using this practice the user agrees that GTE Telephone Operations will have no liability (to the extent permitted by applicable law) for any consequential, incidental, special, or punitive damages that may result.

## 2. Overview

---

- 2.1 Scope** The electrical protection and grounding requirements described in this practice are applicable to the following types of installations:
- Radio Transmission systems.
  - Point-to-Point Microwave systems.
  - Radio Repeater Stations/sites.
  - Rural Subscriber Radio Sites (e.g., Basic Exchange Telecommunications Radio Service [BETRS]).
  - Cellular or wireless sites.
  - Digital synchronization systems.
  - Global Positioning System (GPS) antennas.
  - Leased sites.
- NOTE:** Refer to GTE Telephone Operations Practice 887-030-087 for electrical protection requirements for satellite earth stations and satellite dishes.

## 2. Overview, continued

---

### 2.2 Definitions

The following chart provides definitions for the acronyms and terms used in this practice.

Acronym or Term	Definition
A	Amperes - unit of current
AC	Alternating Current
ACEG	Alternating Current Equipment Grounding
Arc	The luminous glow caused by electrical current flowing through ionized air or gas between separate electrodes or contact points.
AWG	American Wire Gauge
BET	Building Entrance Terminal
BETRS	Basic Exchange Telecommunications Radio Service
Bonding	The permanent joining of metallic parts to form an electrically conductive path, which ensures: <ul style="list-style-type: none"><li>• Electrical continuity.</li><li>• The capacity to conduct safely any currents likely to be imposed.</li></ul>
Building Steel	The structural steel or concrete-encased reinforcing steel (rebars).
CO	Central Office
COE	Central Office Equipment
COEC	COE Construction
COEE	COE Engineering
Common Bonding	The interconnecting of separate ground electrodes necessary at locations where common grounding cannot, or has not, been used.
Conductor	A material, usually wire, cable, or bar, suitable for carrying an electrical current.
Cone of Protection	The area of protection provided by a properly grounded air terminal.
CVGB	Cable Vault Ground Bar

(continued)

## 2. Overview, continued

---

### 2.2 Definitions, continued

Acronym or Term	Definition
Effectively Grounded	Connected permanently to earth (ground) and having sufficient current-carrying capacity to prevent hazardous voltages from building up.
Enclosure	A housing or cabinet for equipment or components.
FAA	Federal Aviation Administration
FCC	Federal Communications Commission
g/m	gram per meter
GHz	Gigahertz (1000000000 Hz)
GPR	Ground Potential Rise: <ul style="list-style-type: none"><li>• A voltage difference between two or more ground electrodes due to the earth's return currents.</li><li>• Exists when currents from either lightning or power system faults flow to ground.</li></ul>
GPS	Global Positioning System
Grounded	Connected directly to ground or through a conducting object that provides a low impedance path to the earth.
Ground Electrode	One or more conductors in direct contact with the earth that provides a connection with the earth.
Halo Ring	A ground ring in the interior of a building or radio hut, which is used to provide voltage equalization.
Henrys	Unit of inductance
HVAC	Heating, Ventilation, and Air Conditioning
Hz	Hertz (unit of frequency)
IGZ	Isolated Ground Zone
Isokeraunic Map	Shows the amount of lightning activity for an area, indicating the average number of days per year on which thunder is heard.
kA	Kiloampere - 1000 amperes

(continued)

## 2. Overview, continued

---

### 2.2 Definitions, continued

Acronym or Term	Definition
kcmil	Thousand circular mils (replaces MCM)
kV	Kilovolts - 1000 volts
Listed	<ul style="list-style-type: none"><li>• Equipment or materials included in a list published by an organization acceptable to the authority having jurisdiction and concerned with product evaluation.</li><li>• The list indicates that the equipment or material:<ul style="list-style-type: none"><li>- Meets appropriate standards.</li><li>OR</li><li>- Was tested and found suitable for use in a specified manner.</li></ul></li></ul>
LPS	Lightning Protection System
m	meter
mm	millimeter - 0.001 meter
Made Electrode	An electrode ground designed and installed for a specific site.
Metallic Member	A noncommunications metallic cable component such as the: <ul style="list-style-type: none"><li>• Shield.</li><li>• Vapor barrier.</li><li>• Strength member.</li></ul>
MGB	Master Ground Bar
MGN	Multi-Grounded Neutral
MHz	Megahertz (1000000 Hz)
NEC	National Electrical Code
NFPA	National Fire Protection Association
NID	Network Interface Device
NRTL	Nationally Recognized Testing Laboratory
OSP	Outside Plant
OSPC	OSP Construction

(continued)

## 2. Overview, continued

---

### 2.2 Definitions, continued

Acronym or Term	Definition
P	Producer
PTD	Protected Terminating Device
PSB	Product Standardization Bulletin
RFI	Radio Frequency Interference
rms	root-mean-square
SBTC	Solid, Bare, Tinned Copper
THHN	Type of insulated conductor. The insulation is thermoplastic and heat resistant.
T&P	Transmission and Protection
UHF	Ultra High Frequency (300 MHz to 3 GHz)
VHF	Very High Frequency (30 MHz to 300 MHz)
Zone of Protection	The space adjacent to a lightning protection system which is practically immune to direct lightning strokes.

### 2.3 References

The following chart provides sources of supplementary information relating to this practice. The documents could be required for performing certain tasks.

See...	For Information About...
117-200-004	Tower Climbing Safety
220-390-001	Radio and Radio Tower - Maintenance Requirements to Comply with FCC and FAA Regulations
390407401	Radio Tower Responsibilities
621-800-200	Tower Radio and Microwave - Bonding and Grounding Network - Installation
621-800-300	Tower Radio and Microwave - Inspection and Maintenance
621-800-700	Tower Radio and Microwave -Acceptance Test Procedures

(continued)

## 2. Overview, continued

---

### 2.3 References, continued

See...	For Information About...
740-250-070	Central Office Grounding System Installation and Inspection
795-805-071	Central Office Grounding Systems - Engineering Applications
795-805-072	AC Service Grounding-Engineering Applications
795-805-074	Inspecting Central Office Grounding and PABX Grounding and Protection
795-805-075	Remote Electronic Serving Area Grounding Systems Engineering Considerations
887-000-050	Electrical Protection - Engineering Fundamentals
887-030-087	Satellite Earth Station Protection - Engineering Considerations
887-600-070	Engineering Fundamentals of Electrode Ground Design
887-600-071	Fundamentals of Ground Measurements
887-600-072	Engineering Methods for Measuring Electrode Grounding Systems
<b>887-795-070</b>	Lightning Protection Systems Risk Assessment Guidelines
887-800-044	Determination of Minimum Separation Between Digital Sites and Electric Power Facilities
903-020-070	Protection -General Considerations
NFPA 70†	National Electrical Code
NFPA 780†	Lightning Protection Code
PSB 0131††	Warning Tags
PSB 1625††	Exothermic Welding
PSB 2149††	Compression Fittings
PSB 4145††	Compression Fittings

## 2. Overview, continued

---

**2.3** † Published by the National Fire Protection Association (NFPA), Quincy, MA.  
**References, continued** †† Product Standardization Bulletins (PSBs) are published by the GTE Telephone Operations Standardization Management Department.

**2.4** **The** Inspection - Central Office Grounding and Electrical Protection, Form 90001528, is referenced in this practice.  
**Form** Order this form through normal supply channels.

## 3. Planning Ahead

---

**3.1** When preparing the engineering specifications for a radio site, consider the following preliminary site information:  
**General**

- Space availability.
- Site elevation above sea level.
- Height of the proposed towers or supporting structures.
- Soil resistivity survey of the area.
- Isokeraunic map of the area.
- Location and height of other structures in the area.

**3.2** The information listed in Section 3.1 aids in estimating the severity and incidence of lightning expected at the proposed site. The design of the electrical protection system is based on the information obtained.  
**Predicting Lightning Incidence**

The presence of an antenna and its supporting structure might not increase the probability of lightning striking a particular location. If the site or the surrounding area is struck by lightning, the antenna and its supporting tower might become the focal point of the strike.

**3.3** Radio sites in rural or remote and sparsely populated areas are very susceptible, and often subjected, to:  
**Rural Areas**

- Direct lightning strikes to the antenna or tower.
- Destructive current surges that might enter the site's equipment and tower lighting circuits originating from the:
  - Serving commercial power.
  - AND/OR
  - OSP telephone facilities.

**NOTE:** The protective grounding considerations for remote radio sites are very important.

### 3. Planning Ahead, continued

---

#### 3.4

#### Locations to Avoid

Avoid locating towers and antennas:

- Too close to a power station.
- In the vicinity of high voltage transmission lines.
- At the end of the commercial power circuit.
- That share the power feed with heavy inductive users (e.g., welding shops, pump stations, factories).
- Cathodic protection fields (including anode beds and rectifier sites).

### 4. Site Construction and Design Considerations

---

#### 4.1

#### Building Types

The radio or microwave station building can be:

- Prefabricated.
- Constructed on site.
- Permanent.
- Temporary.

**NOTE:** The protection and grounding requirements are the same regardless of the type of construction.

#### 4.2

#### Building Construction

Bond and ground the following structural steel and concrete reinforcing steel:

- Footing reinforcing steel.
- Slab welded wire mesh.
- Wall reinforcing steel.
- Steel columns.
- Steel beams/bar joists.
- Reinforcing steel in poured roof slabs.
- Poured concrete building walls.
- Steel roof supports.

**NOTE:** Common bond and ground steel reinforcing rods before the concrete is poured.

The electrical contractor performs all bonding and grounding to the site's outer grounding system (Lead 1) during the construction phase of the building.

## 4. Site Construction and Design Considerations,

continued

---

- 4.3 **Site Inspections** Conduct frequent inspections during the construction phase to ensure that all grounding arrangements are made according to the grounding design specifications

The outer grounding system is:

- Inspected during construction and before backfilling.
- Measured shortly after completion and six months after completion to ensure that the design objectives are met.
- Measured 12 months after completion, and yearly thereafter, to ensure that the grounding system has not degraded.

**NOTE: Do not retrofit (or upgrade) established sites that do not meet all the requirements of this practice unless there are documented occurrences of equipment damages and/or service affecting conditions.**

- 4.4 **Fuel Tanks**

The following chart describes rules for installing fuel tanks at radio sites.

Rule	Action
1	Do not place fuel tanks between towers and buildings.
2	Do not bury a fuel tank close to the tower ground ring if the tank is: <ul style="list-style-type: none"><li>• Metallic.</li><li>• Not bonded to the site's grounding system.</li></ul>
3	Make the distance between the tower and the tower ground ring greater than the arcing distance that could develop, for example: <ul style="list-style-type: none"><li>• If the soil resistivity is less than 100 meter-ohms, the minimum distance should be 15 feet (4.6 m).</li><li>• If the soil resistivity is more than 100 meter-ohms but less than 1000 meter-ohms, the minimum distance must be 25 feet (7.6 m).</li></ul>
4	Bond the metallic fuel tank to the site's grounding system to avoid fire or explosion as follows: <ul style="list-style-type: none"><li>• Provide a disconnecting means in the bond to allow for periodic testing of the grounding system.</li><li>• Connect the grounding conductor to the fuel tank by clamping it to the filler pipe.</li><li>• Bond the buried metal fuel feed line (from the tank to the building) to the external ground ring at the point where they cross.</li></ul> <p><b>WARNING: Do not weld on, or drill, the fuel tank itself.</b></p>

**NOTE: The bonding of metallic fuel tanks and their ancillary equipment (e.g., metallic fuel lines, etc.) must not disrupt any cathodic protection measures applied to the tank (see Section 5.4).**

# 5. Electrical Protection Considerations

---

## 5.1 General

Protect radio sites from lightning and power line surges. Study every site to analyze:

- Soil resistivity and terrain configuration.
- Possible GPR.
- Exposure to:
  - Lightning.
  - Power surges.
  - Power transients.

## 5.2 Protection Elements

The most common elements used in the protection of radio sites (equipment and structures) include:

- Bonding.
- Grounding.
- Shielding.

## 5.3 Common Bonding

Common bonding and grounding of all metal components and objects in a radio site, both inside the building and between the internal and external grounding systems, is essential.

Bonding connections and multiple paths to ground prevent arcing and reduce dangerous voltage differences that might appear at the time of a lightning strike or during power fault conditions.

Make all bonding attachments to clean, unpainted metal surfaces.

Make bonding connections to elements under tension (such as down guys) using compression fittings.

**WARNING: Do not weld grounding conductors to the structural members of towers, including down guys and anchor rods.**

## 5.4 Common Grounding

Common grounding of all the conducting components of the structure (e.g., building, hut, and enclosure) and the site's radio or transmission equipment reduces possible differences in voltage that might create a shock hazard or cause arcing and the subsequent damage.

Bond all metallic objects (such as water pipes, conduits, metal fuel tanks without cathodic protection, metal fences, etc.) that are within 6 feet (1.8 m) of the ground ring or from any other grounded conductor to Lead 1 or to the grounded conductor.

**CAUTION: Isolate metal fuel tanks with cathodic protection from the grounding system and the fuel line when a separation of 6 feet (1.8 m) cannot be obtained. Use heavy-duty carbon protectors with 0.020 inch (0.51 mm) gap or equivalent.**

**NOTE: Bond Intervals must not exceed 20 feet (5 m). Place bonds across fence openings or gates.**

Use Lead 6 to bond metallic fence posts and/or metallic fence sections within 6 feet (1.8 m) of the ground ring. Make the connection of Lead 6 to the fence with a mechanical connector to allow for its removal for testing. Bonding intervals along the fence should not exceed 20 feet (6 m). Refer to GTE Telephone Operations Practice 795-805-075 for additional information.

## 5. Electrical Protection Considerations, continued

---

### 5.5 Grounding Systems

The outer ground ring, or equivalent grounding electrode system, around the tower and building provides:

- The means to equalize potential to the earth surrounding the building and tower.
- The means to help dissipate lightning currents.
- A contribution to the grounding electrode system to maintain the desired ground resistance.

### 5.6 Grounding Connections

Grounding connections to the outer grounding electrode system are preferred because they allow lightning currents to go directly to the earth without entering the building.

### 5.7 Shielding

Shielding, which can be provided most effectively and most economically during construction, is provided by:

- Bonding electrically reinforcing steel (rebar) in the wall, roof, and floors.  
**OR**
- Providing a metallic mesh that is embedded in the building walls and grounded to the site's grounding system.

Effective shielding helps mitigate RFI.

**NOTE: Post-construction shielding of individual apparatus and interconnecting cables is likely to be more difficult and expensive.**

## 6. Material Requirements

---

### 6.1 Materials

Use only GTE-approved materials for the:

- Site grounding system.
- Electrical protection components.
- AC wiring.

### 6.2 Nationally Recognized Testing Laboratory (NRTL) Listing

All materials for bonding, grounding, and AC power must be listed for the purpose by a NRTL as required by the NEC.

### 6.3 Substitutions

All material that is not GTE standard must be approved via the deviation process specified in GTE Telephone Operations Practice 887400401.

**CAUTION: Substituting untinned bare copper wire (for tinned) increases the risk of corrosion of the wires.**

## 6. Material Requirements, continued

---

### 6.4 Ground Rod Specifications

The minimum specifications for ground rods are:

- 8 feet (2.5 m) long by 5/8-inch (16 mm) diameter galvanized steel.
- Connected to the ground ring.
- Driven at least 8 feet (2.5 m) into the soil.

### 6.5 Connections

Make connections to the ground ring and rods using GTE-approved:

- Exothermic welds (PSB 1625).
- Compression fittings (PSB 2149 or PSB 4145).

**NOTE:** Permanent connections should be either exothermic welds or irreversible compression connections. Make connections that will be removed during testing using mechanical-type fittings.

## 7. Grounding Conductors

---

### 7.1 Conductor Inductance

The inductance of grounding conductors is the main cause of potential differences that build up along the discharge paths when lightning currents travel through the grounding system.

The use of heavy gauge conductors presents a low resistance, but does not notably change the inductance or the voltage drop that develops.

To minimize the effects of overall inductance of the discharge path:

- Keep the length of conductors to a minimum.
- Use multiple (parallel) conducting paths.

To limit the voltage difference that might appear between the individual discharge paths, bond connections often. This equalizes the voltage.

EXAMPLE:

A radio mast is grounded through 40 feet (12.2 m) of #6 AWG SBTC wire. The inductance of this conductor is 20.6 microhenrys and its resistance is 0.016 ohms.

If a lightning discharge peaking at 10,000A in 2 microseconds follows this conductor, the voltage developed between the ends of the conductor would be:

$$V = R * i + L (di/dt)$$

Where:

- $di/dt$  is the rate of increase of the current with respect to time.
- L is the inductance of the wire in henrys.
- i is the current discharging in amperes.
- R is the resistance of the wire in ohms.

## 7. Grounding Conductors, continued

---

7.1

### Conductor Inductance, continued

Assuming  $di/dt$  is the average of the rise of 10 kA current in 2 microseconds:

$$di/dt = 10,000/2 * 10^{-6} = 5 * 10^9 \text{ A/second}$$

The voltage developed along the conductor by the inductance (self-inductance) alone is:

$$V = L * (di/dt) = (20.6 * 10^{-6}) * (5 * 10^9) = 103,000 \text{ volts}$$

The voltage developed along the conductor by the resistance component alone is:

$$V = R * i = 0.016 * 10,000 = 160 \text{ volts}$$

The voltage drop caused by the resistance component is negligible when compared to the large voltage drop generated by the self-inductance of the wire.

Using a conductor that is eight-fold heavier (such as 4/0 AWG) results in an inductance of 18 microhenrys, which is 12% less than the inductance of a #6 AWG conductor.

If two conductors #6 AWG connected in parallel and spaced 3 feet (1 m) apart are used, the total inductance of the combination, including the mutual inductance between them (13.2 microhenrys) is a reduction of 36% from the value of one conductor alone.

7.2

### Conductor Requirements

Use conductors no smaller than those specified in this practice for all common bonding and grounding connections to ensure:

- Adequate conductivity for lightning strike currents.
- Sufficient mechanical strength.

To minimize the effects of corrosion use:

- Tinned solid copper conductors when burying them.
- Galvanized ground rods.

Bond the grounding conductor and the grounding structure to eliminate arcing to grounded structures when the grounding conductor is within 6 feet (1.8 m) of the following grounded metallic structures:

- Water pipes.
- Gas pipes.
- Metal conduit.

**NOTE:** These grounding conductors should preserve a downward to horizontal course and be:

- As straight as possible.
- Avoid sharp turns.

## 7. Grounding Conductors, continued

---

### 7.3 Grounding Conductor Requirements

All grounding conductors must meet the following requirements:

- Do not use U-shaped grounding conductor runs or bonding layouts to reduce arc overs.
- Run in nonmetallic conduit.
- Run through nonmetallic sleeves in:
  - Floors.
  - Walls.
  - Ceilings.

**NOTE:** If the use of metallic conduit cannot be avoided, bond both ends of the conduit to the grounding conductor.

- Avoid long runs of ground leads.
- Keep bends in conductors to a minimum.

**NOTE:** 12 inches (305 mm) is the minimum bend radius for #2 AWG wire.

- Always preserve a downward to horizontal course for grounding conductors.
- Ground conductors **must never** be:
  - Encircled with metal clamps.
  - Placed through metal walls, metal plates, or short sections of metal conduit.
  - Placed less than 1 foot (305 mm) from DC power cables, high frequency cables, etc.

### 7.4 Ground Wire Physical Protection

The following chart describes the rules for determining if a ground wire should be in conduit.

If a Ground Wire Is...	Then...
Not subject to physical damage	It could be attached directly to noncombustible walls. In most cases, use a nonmetallic U-guard or nonmetallic conduit up to a height of 8 feet (2.5 m).
Placed in metallic conduit	A choking effect occurs, which increases with current. Eliminate the choking effect by: <ul style="list-style-type: none"><li>• Bonding the conduit to the ground wire at both ends of the conduit.</li></ul> OR <ul style="list-style-type: none"><li>• Using nonmetallic conduit that meets NEC requirements.</li></ul>

### 7.5 Lead Designations

See Exhibit 8 for lead designations and grounding conductor sizes.

# 8. Grounding System

---

8.1

## Attributes

A well-designed grounding system:

- Provides an equalized ground reference for equipment operation.
- Controls potential differences to minimize electric shock to personnel.
- Reduces noise by providing low-impedance paths between:
  - Frames.
  - Systems.
  - Earth.
- Provides a degree of reliability for the service life of the equipment at the site.
- Protects equipment from damage or fire hazard by diverting excessive fault and lightning currents to earth.

8.2

## Purpose

Properly designed and installed grounding systems are necessary to dissipate lightning currents to the earth before they are able to enter the radio building. It is impossible to prevent all surge currents from entering the building due to the multiple metallic paths between the building interior and exterior; however, significant amounts of the surge current can be diverted and controlled.

The grounding system described in this practice provides:

- For personnel safety by equalizing potential differences between frames, ironwork, and other metallic elements which minimizes electrical shock hazards.
- The lowest practical impedance path for lightning surges to flow to earth.
- A low impedance path to allow the proper operations of overcurrent protection devices during fault conditions.
- A low impedance ground reference for proper equipment operation.
- A reliable and low maintenance grounding network.

8.3

## Improper Grounding

Improper grounding can result in:

- Erratic equipment operation.
- Noisy circuits.
- Premature component failures.
- Catastrophic equipment failure.
- Potential safety hazards.

8.4

## Components

**The** grounding system of a site is composed of:

- Grounding electrodes.
- Power company neutral (MGN).
- Exterior metallic water pipes.
- Grounding conductors for:
  - Electrodes.
  - Equipment.
- Bonding conductors.

## 8. Grounding System, continued

---

### 8.5 Typical Site Arrangement

Grounding arrangements depend on the:

- Type of building.
- Antenna support used.
- Physical location of the site.

The following chart describes radio station grounding requirements.

If...	Then...
Stand-Alone Site	Install a ground ring (Lead 1): <ul style="list-style-type: none"><li>• With ground rods.</li><li>• Connected to MGB (Lead 5).</li></ul>
Colocated Sites	Connect the ground ring for the support structure or station hut to the: <ul style="list-style-type: none"><li>• Ring for the CO.</li></ul> OR <ul style="list-style-type: none"><li>• Existing grounding electrode.</li></ul>
Temporary	See Section 12.11 for specific requirements.

**NOTE:** Colocated means a radio site and a CO in the same or adjacent lots so that the distance between the two ground rings is 50 feet (15.2 m) or less. The radio site (tower and/or hut) might or might not be owned (or controlled) by GTE Telephone Operations.

Exhibits 1 and 2 show a typical grounding arrangement for fixed radio stations and microwave relay stations.

### 8.6 Leased Sites

Sites that GTE Telephone Operations leases from other parties require the following, as a minimum, from the lessor before adding equipment to the site:

- The structure (tower) must be grounded.
- The minimum acceptable grounding system must consist of two galvanized steel ground rods 8 feet (2.5 m) long and 5/8 inch (16 mm) in diameter, driven into the ground, placed 180 degrees apart, and with no less than 10 feet (3 m) of separation between them.
- The ground rods must be bonded with a minimum of #6 AWG SBTC wire to the nearest leg(s) of the tower.
- Self-supporting towers with more than 5 feet (1.5 m) in base width must have, as a minimum, one ground rod per leg.

**NOTE:** These requirements are in compliance with Clause 12 of Standard ANSI/TIA/EIA-222-F (1996).

# 9. Site Grounding Electrode

---

9.1

## Design

Design the Site Grounding Electrode systems:

- Based on soil resistivity measurements at the spacing/depth required by local soil conditions and resistance objectives.
- To meet the ground resistance objectives.

**NOTE: GTE Telephone Operations Practice 887-600-070 provides the formulas for designing the electrode grounding system.**

The T&P Engineer/Administrator must approve the site grounding electrode system.

9.2

## Recommended Ground Resistance Objectives

The recommended resistance objective for telephone constructed grounding electrodes for radio and microwave sites should be equal to or less than the objective shown in the following chart.

Objective*	Equipment Type
2 ohms	Radio towers (60 feet [18 m] or taller).
2 ohms	CO buildings and huts colocated with radio towers of any height.
5 ohms	<ul style="list-style-type: none"><li>• BETRS cluster sites.</li><li>• Pad-mounted equipment colocated with towers of less than 60 feet (18 m).</li></ul>
25 ohms	Rural radio (BETRS) at customer locations and at nonclustered sites.

**NOTES: \*Grounding electrode alone measured by the fall-of-potential method using a ground resistance test set.**

**Refer to:**

- **GTE Telephone Operations Practice 795-805-071 for objectives for COs and large remote buildings.**
- **GTE Telephone Operations Practice 795-805-075 for objectives for small huts and DLCs.**

9.3

## Inability to Meet Objectives

Meeting the recommended grounding electrode resistance objectives of Section 9.2 might not be economical in areas with:

- Unfavorable soil conditions.
- Very high earth resistivity.

## 9. Site Grounding Electrode, continued

---

### 9.3 Inability to Meet Objectives, continued

In these locations, the lowest combined ground resistance economically feasible (maximum 5 ohms) might be obtained by bonding before measuring the following when available:

- Telephone company ground electrodes.
- Power company neutral (MGN).
- Exterior metallic water pipes.

**NOTES:** These elements can be added to the grounding system of a radio site but must not be used as a single and only electrode (see Section 9.8).

Complete a Deviation Request Form per GTE Telephone Operations Practice 887-000-001 and approved by Area/Region Support Staff (Protection).

### 9.4 Ground Electrodes

GTE-designed site grounding electrodes might include:

- Ground rings.
- Deep electrodes.
- On-site metallic water pipe (20 feet [6 m] direct buried minimum).
- Ground fields.
- Concrete encased steel and/or wire.
- Building steel when bonded and effectively grounded.

### 9.5 Ground Ring

An external ground ring for the tower, building, or both is the preferred ground electrode for radio sites. The ground ring is composed of #2 AWG SBTC wire:

- Buried at least 30 inches (762 mm) below grade level or below the frost line (whichever is deeper).
- Spaced at least 2 feet (610 mm) from building foundations and tower footings.
- With a bend radius of at least 24 inches (610 mm).
- With a minimum of four ground rods (one at each corner) spaced a minimum of 10 feet (3 m) apart.

**NOTE:** Provide radials if ground rods cannot be driven and it is not feasible to drill (see Section 9.10).

### 9.6 Minimum Made Electrode

A minimum made electrode (always required) includes 20 feet (6 m) of #2 AWG SBTC wire with two or more 5/8-inch x 8 feet (16 mm x 2.5 m) GTE standard rods placed at 8 feet (2.5 m) intervals along a ring formed by the wire (see Section 6.4).

### 9.7 Placing Ground Rods

Place all ground rods in undisturbed soil and below the frost line.

## 9. Site Grounding Electrode, continued

---

### 9.8 Supplemental Electrodes

Place supplemental electrodes if rock formations, other terrain conditions, or soil resistivity do not allow the objective to be met. These might include (refer to GTE Telephone Operations Practice 887-600-070):

- Deep driven well(s).
- Metal plates.
- Buried radial wires.
- Low resistivity material:
  - Concrete.
  - Bentonite.

### 9.9 Providing Access to Connections

Provide suitable access (e.g., a hand hole) to those points where Leads 3, 5, 25, 27, and 28 connect to Lead 1. This allows:

- Quality inspections.
- Isolation of segments to be tested, such as:
  - Ground ring.
  - Building steel.
  - Other ground fields (CO, tower, etc.).

## 9. Site Grounding Electrode, continued

### 9.10 Radial Grounding Conductors

Provide radials if ground rods cannot be driven and it is not feasible to drill. When radial grounding conductors are necessary, use the following chart to determine requirements.

**NOTE:** Low resistance in radial grounding arrangements is desirable but not essential. Low resistance in the dissipating path of strike currents into the earth is of secondary importance when compared to the major objective of controlling voltage gradients and voltage differences between structures close to the radio equipment.

If...	Then...
Fixed radio stations are constructed on sites where bedrock prevents placing ground rods	Provide a network of buried grounding conductors (see Exhibit 6): <ul style="list-style-type: none"> <li>• Radiating from each base of the antenna and building corner.</li> <li>• Connecting to the ground rings.</li> </ul>
Radial grounding conductors are required	Use #2 AWG SBTC wire: <ul style="list-style-type: none"> <li>• Connected to the ground ring by the methods listed in Section 6.5.</li> <li>• Buried at least 30 inches (762 mm) below grade level.</li> </ul>
Adequate contact cannot be reached with the soil at 25 feet (7.6 m)	Extend each radial wire as far as necessary to obtain the desired resistance. Wire lengths of up to 500 feet (152 m) might be required. <p><b>NOTE:</b> The conductor length must not be less than 25 feet (7.6 m).</p> <p>Refer to GTE Telephone Operations Practice 887-600-070 for formulas to calculate the ground resistance of buried wires.</p>

### 9.11 Ground Rings

The typical tower ground ring:

- Consists of #2 AWG SBTC wire.
- Is buried at least 30 inches (762 mm) below grade level or below the frost line (whichever is deeper).
- Is spaced at least 2 feet (610 mm) from the outside face of the concrete piers for the tower footings.

Bond the tower ground ring to the (see Exhibits 3 through 5):

- Tower grounding plate from two directions.
- Tower legs.
- Ground rods.
- Site's or building ground ring if within 50 feet (15.2 m).
- Feed line ground bar.

## 9. Site Grounding Electrode, continued

---

### 9.12 Fences

If a fence is located within 25 feet (7.6 m) of the tower ground ring, or 6 feet (1.8 m) from the building ground ring, bond the:

- Fence to the ring.
- Fence posts to the ring at distances not to exceed 20 feet (6 m).
- Openings (e.g., gates) across the fence.

**NOTE:** Use #2 AWG (minimum) SBTC wire for bonding purposes.

## 10. AC Power Grounding Electrode

---

### 10.1 Power Service Ground

The protective grounding scheme for the AC service (including the grounding conductor gauge) must meet the requirements of the NEC and the local codes (ordinances).

Connect the conductor used for the AC power service ground (Lead 4) to the metallic water pipe system (if present).

Bond the AC power service ground for radio and microwave sites to the MGB (Lead 13) or the building's external ground ring (see Exhibit 9).

**NOTE:** Connect the MGB and the building's external ground ring to the tower ground ring.

## 11. Antennas and Transmission Lines

---

### 11.1 General

This section describes the electrical protection and grounding considerations for:

- Radio and microwave antennas.
- Associated transmission (feed) lines.

### 11.2 Antenna Grounding

When antennas are mounted on metallic support structures, the antenna is bonded to the tower by the metallic mounting brackets.

When antennas are mounted on wooden support structures, the antenna is bonded to the pole vertical ground wire by means of a strap from the metallic mounting brackets to the ground wire.

### 11.3 Antenna Types

The main types of antennas are:

- Parabolic antennas.
- VHF/UHF antennas.

# 11. Antennas and Transmission Lines, continued

---

## 11.3 Antenna Types, continued

### 11.3.1 Parabolic Antennas

Point-to-point microwave radio stations use parabolic antennas that are 2 feet (610 mm) to 15 feet (4.6 m) in diameter. A parabolic antenna can be:

- Mounted on a roof or a tower.
- Connected to radio equipment by a coaxial transmission line or a waveguide.

**NOTE: Some antenna systems might use a tower-mounted passive reflector that is bonded to the tower.**

### 11.3.2 VHF/UHF Antennas

Use coaxial and collinear array of multidipole antennas at mobile base stations and rural radio stations operating in the VHF/UHF range. Multidipole arrays are directly grounded antennas.

A star gap protects the coaxial type of antenna between the inner coaxial conductor (whip) and the outer coaxial conductor (skirt) of the antenna.

Some types of coaxial dipole antennas have 1/4 wavelength shorting stubs at their base. Tuning this stub to 1/4 wavelength of the operating frequency prevents arcing between the whip and the skirt of the antenna.

Under normal conditions, the stub does not attenuate the signal level. The stub:

- Provides a path to ground for lightning surges.
- Protects the dielectric of the coaxial transmission line.

**NOTE: Coaxial transmission lines have comparatively high dielectric strength and, consequently, arcing is more likely to occur at the equipment end.**

The star gap between the whip and the skirt of the coaxial antenna:

- Protects the radio station by diverting a large portion of a lightning strike's current to ground.
- Confines the voltage between the whip and the skirt of the coaxial antenna to the limit prescribed by the arc drop across the gap. Determine this limit by the:
  - Insulation resistance of the gap.
  - Induced voltage created by the current flowing in the skirt.

Ground the radiating element of the collinear-array type omnidirectional gain antenna in order to divert a lightning strike to ground.

# 11 . Antennas and Transmission Lines, continued

---

## 11.4 Coaxial Transmission Lines

In addition to the possibility of dielectric failure in coaxial transmission lines, electrical stresses (e.g., heavy current flows) in the outer conductor of the coaxial line produce strong mechanical forces that can:

- Crush the outer conductor.
- Cause a short circuit to the inner conductor.

**NOTE:** This is true in air or gas dielectric coaxial lines.

Provide parallel paths to ground to reduce:

- Heavy lightning currents in the coaxial outer conductor.
- High voltage developed in the coaxial inner conductor.

A metallic antenna support provides a path to ground when bonded to the coaxial outer conductor at the base of the support.

The following chart describes how to protect coaxial transmission lines.

---

If...	Then...
Coaxial transmission lines, especially those having air or gas dielectric, are used on wood poles	Bond the outer conductor at the top and bottom of the pole to the ground wire.
The coaxial line is covered with a metallic U-guard	Bond the U-guard to the: <ul style="list-style-type: none"><li>• Outer coaxial conductor.</li><li>• Ground wire at the points where the coaxial line enters and leaves the U-guard. Bond successive U-guard sections to reduce arcing.</li></ul>

---

These arrangements (see Exhibits 6 and 7) reduce the occurrences of:

- Damage to the coaxial line.
- Arcing at the equipment.

Lightning surges tend to divide between the coaxial outer conductor and the U-guards. Because of the mechanical strength of solid dielectric coaxial lines, the chance of crushing their dielectric is greatly reduced. The:

- 3/8-inch (9.5 mm) diameter air dielectric coaxial line withstands a surge potential of approximately 7 kV.
- 7/8-inch (22.2 mm) diameter air dielectric coaxial lines and the solid dielectric lines will withstand substantially higher voltages.

## 12. Antenna Support Structures

---

### 12.1 General

This section describes specific electrical protection considerations for antenna support structures (towers).

### 12.2 Antenna Locations

Antennas at radio sites are typically mounted on wood or metal supports. In some cases, the antenna supports (towers) are mounted on the roof of a building.

Occasionally, the antenna might be mounted on the side wall of a building or on a parapet wall using special braces or supports (see Section 12.7 for grounding requirements).

Mounting towers or antennas on a roof could damage the structural integrity of the building and/or void the warranty of the roof. The Support Assets - Real Estate and Building Services group must approve design plans.

**NOTE:** The presence of an antenna and its supporting structure on the roof of a building is not expected to significantly increase the probability of lightning striking the building. However, if lightning does strike, the antenna and its supporting tower probably becomes the focal point of the strike.

### 12.3 Types of support Structures

The main antenna support structures (towers) that can be installed at radio sites are:

- Metallic guyed.
- Metallic self-supporting.
- Wooden structures (poles).

The towers can be installed:

- At grade level (surface).
- OR
- On the roof of a building.

#### **12.3.1 Guyed Metallic Towers**

These are structures that require:

- Multiple anchors and down guys.
- Upright support members (legs) on a foundation or pier.

#### **12.3.2 Self-Supporting Metallic Towers**

These are free-standing structures that do not need supporting elements other than the upright support members (legs) on a foundation or piers.

#### **12.3.3 Wooden Structures (Poles)**

These are either free-standing or guyed structures:

- Placed on a foundation.
- OR
- Partially buried into the soil.

**NOTE:** Poles typically do not exceed 60 feet (18 m) in height.

## 12. Antenna Support Structures, continued

---

### 12.4 Guyed Towers

Guyed towers should have a ground ring around the base with:

- Four 8 feet long (2.5 m) ground rods.
- #2 AWG SBTC conductor:
  - 30 inches (762 mm) below grade level.
  - 24 inches (610 mm) from concrete foundation or pier.
- #2 AWG SBTC conductor from tower ring to tower base.
- #2 AWG SBTC conductor from tower ring to building ring.

**NOTE:** When a ground ring cannot be established, use radials as described in Section 9.10.

Bond the ring to the tower as described in Section 9.11.

Use guyed anchors to brace antenna supports. Each guyed anchor should have a ground ring around it as follows:

- Four 8 feet long (2.5 m) ground rods.
- #2 AWG SBTC conductor:
  - 30 inches (762 mm) below grade level.
  - 24 inches (610 mm) from concrete foundation or pier.
- #2 AWG SBTC conductor from anchor rung bonded to each down guy.

The following chart shows what to do if the:

- Soil has high resistivity.  
OR
- Guy wires are anchored in concrete.

---

Step	Bonding for Poor Soil Conditions or Guy Wires Anchored in Concrete
1	Drive four 5/8-inch (16 mm) galvanized ground rods in a square (or rectangular) pattern around each anchor.
2	Bond the ground rods to each other.
3	Clamp to the guy wires with a #2 AWG SBTC wire (see Exhibit 5).

---

**NOTE:** Ground rods tend to:

- Equalize the potentials in the earth around the anchor.
- Reduce the possibility of damage to the concrete in the event of heavy lightning discharge. In areas of high earth resistivity, consider bonding these ground rods to the:
  - Tower base ground ring.
  - Site main (outer) ground ring.

## 12. Antenna Support Structures, continued

---

### 12.5 Self-Supporting Tower Footings

Embed the footings of self-supporting towers in concrete foundations or piers. Self-supporting towers should have a ground ring around the base as follows:

- Composed of #2 AWG SBTC wire.
- Buried at least 30 inches (762 mm) below grade level.
- Spaced at least 24 inches (610 mm) from building foundations and tower footings.
- With a bend radius of at least 12 inches (305 mm).
- With a minimum of four ground rods (one at each corner of the ring) spaced a minimum of 10 feet (3 m) apart.

Use the grounding arrangements shown in Exhibits 3 and 4.

**NOTE: When a ground ring cannot be established, use radials (see Section 9.10).**

Bond the ring to the tower as described in Section 9.11.

### 12.6 Sites with Wood Poles

In some cases, a radio site consists only of a wood pole supporting the antenna and the radio equipment cabinet.

All wood poles should have a vertical ground wire (#2 AWG SBTC) terminating in either:

- Ground rods.  
OR
- Radials.

See Section 9.10.

Common bonding and grounding principles used on separate building and tower sites also apply in this case. In addition, the following requirements must be met:

- Any electric power conduit must extend and terminate above any telephone attachment (cable, wire, or drop) at a point where the weatherhead is near the power circuit attachments or warning light).
- The conduit from the weatherhead to the power meter should be at least 20 feet (6 m) long. This aids the operation of the power arrester at the weatherhead.

The grounding system must consist of #2 AWG SBTC wire:

- Buried at least 30 inches (762 mm) below grade level.
- Bonded to at least two ground rods or two radial conductors (see Exhibits 6 and 7).

## 12. Antenna Support Structures, continued

---

### 12.7 Roof-Mounted Towers

When the antenna support or tower is mounted on the roof of a building, design a grounding system that:

- Uses regular lightning protection cables and hardware.
- Follows the recommendations of the NPFA-780 Lightning Protection Code.
- Places a wire ring (roof ring) around the antenna support or tower.
- Connects the tower base footings to the:
  - Tower ground ring.
  - Waveguide, or coaxial, outer conductor.
  - Lighting AC branch circuit metallic conduit and green wire (ACEG).
  - Lightning arrester ground.
- Connects:
  - Antenna metal members to the tower or antenna support structure.
  - Antenna support structure to ring.
  - Lightning protection system perimeter wires.
  - Ring to any other metallic object on the roof within flashover range.

See Exhibit 16.

**NOTE:** Coordinate the LPS of the building and the grounding system for the tower.

The following chart describes how to select the wire for the ground leads and down conductors according to the height of the antenna plus roof.

If the Height Is...	Use Ground Leads of...
Less than 75 feet (22.8 m)	Class I lightning cable: <ul style="list-style-type: none"><li>• Copper.</li><li>• 187 lbs/1000 ft (278 g/m).</li><li>• 57.4 kcmil.</li><li>• Strands of no less than #17 AWG.</li></ul>
More than 75 feet (22.8 m)	Class II lightning cable: <ul style="list-style-type: none"><li>• Copper.</li><li>• 375 lbs/1000 ft (558 g/m).</li><li>• 115 kcmil.</li><li>• Strands of no less than #15 AWG.</li></ul>

## 12. Antenna Support Structures, continued

---

### 12.8 Down Conductors

A roof-mounted tower or antenna mast of any size requires at least two down conductors (Lead 22) from opposite sides of the roof ground ring down the building wall to connect to:

- A ring around the building (preferred).  
OR
- Two or more rods.

Additional down conductors are needed for each 100 feet (30 m) of building length.

**NOTE: These down conductors are in addition to the ones used in the lightning protection system.**

See Exhibit 16 for a typical method of grounding of a roof top tower.

The following chart describes how to protect the down conductors.

If Down Conductors...	Then...
Enter corrosive soil	<b>CAUTION: Never use aluminum conductors below grade level.</b>  Protect against corrosion using corrosion resistant conductors and hardware: <ul style="list-style-type: none"><li>• Up to a level no less than 3 feet (1 m) above grade.</li><li>• For the entire length below grade level.</li></ul>
Are located in or on: <ul style="list-style-type: none"><li>• Driveways</li><li>• Runways</li><li>• Public walks</li><li>• Other similar locations</li></ul>	Protect against physical damage.  <b>NOTE: Protect down conductors for a minimum of 8 feet (2.5 m) above grade level.</b>
Are inside walls or other concealed installations	Provide labels inside and outside the building to indicate the location of down conductors.

### 12.9 Roof Conductors

Support roof conductors every 3 feet (1 m) using:

- No-nail paste down cable fasteners.  
OR
- Pan-type base ridge cable supporters.

## 12. Antenna Support Structures, continued

---

### 12.10 Antenna Support Protection

The following chart describes how to provide appropriate antenna support(s):

**NOTE:** Secondary conductor cables must meet the requirements of NFPA 780. Copper conductors must have 14 strands each of no less than #17 AWG.

If...	Then...
me antenna support is mounted on a building with a metal frame and the antenna support is metal	Bond the antenna support and the coaxial outer conductor to the metal building frame with Class II secondary conductor copper cable and approved hardware (clamps, etc.).
Guy wires are attached to an antenna support	Bond the antenna support to the metal building frame, where practical, with Class II secondary conductor copper cable.
Guy anchors are installed in highly resistive soil or in concrete	Connect the anchors to the ground rod arrangement as described in Section 12.7.
The building does not have a metal frame	Provide a system of down leads that conduct lightning strike currents to ground without arcing to other grounded objects.
There is less than 6 feet (1.8 m) of separation between a grounded antenna support or grounding conductor and lightning protection wires or other grounded structures such as: <ul style="list-style-type: none"><li>• Metal pipes</li><li>• Conduits</li><li>• Smoke pipes</li></ul>	Provide bonding connections using Class II secondary conductor copper cable.
There are less massive metal objects such as: <ul style="list-style-type: none"><li>• Gutters</li><li>• Downspout</li><li>• Ventilators</li></ul>	Provide bonding connections at their upper end to the grounding conductor or grounded antenna support.
The metal object is of considerable length	Provide additional bonding at the lower or farthest end.  <b>NOTE:</b> This grounding arrangement reduces the possibility of side flashes when the separation is less than 6 feet (1.8 m). Side flashes can damage a building or set it on fire.

---

## 12. Antenna Support Structures, continued

---

- 12.11** Temporary towers, for the purposes of this document, are those towers that are:
- Grounding Requirements of Temporary Towers**
- Not designed for permanent installations.
- AND
- Are used for a short time frame or for emergency service restoration.

Ground all temporary towers via:

- A ground rod.  
OR
- Other approved and verifiable ground such as an MGN.

### 12.11.1 Short Time Usage

If the site is for a one-time use only, ground via a ground rod and use an air terminal if no taller structure is in close proximity.

**NOTE: This is typically less than 24 hours.**

### 12.11.2 Extended Temporary Usage

If the site is used on a regular basis, but not permanently, install a permanent ground ring, especially when the site is in use for several days (over 24 hours).

Install the ring and other protection items in such a way that they are reusable.

## 13. AC Power Service Protection

---

- 13.1** The AC power facilities that supply commercial AC service to the building are susceptible to lightning hits. It is reasonable to expect that voltage transients will be impressed on AC operated equipment inside the building.
- General**

Power companies typically install lightning arresters on the primary side of the power distribution transformer. Arresters at the primary side provide adequate protection for distribution transformers against lightning surges.

**NOTE: Arresters are protective devices used on power circuits. Protectors are protective devices used on telephone circuits.**

**13.2**  
**Service**  
**Arresters**

Although the power facilities might be equipped with primary arresters, surge voltages might:

- Appear to be impressed on secondary power circuits.  
OR
- Enter the radio room with enough magnitude to cause equipment damage.

## 13. AC Power Service Protection, continued

---

### 13.2 Service Arresters, continued

AC service arresters are protective devices that are used to limit abnormal surge and transient voltages on power circuits by discharging the longitudinal surge currents on a phase conductor either to ground or neutral. Refer to GTE Telephone Operations Practice 795-805-072 for a list of GTE standard arresters. See Exhibits 10 through 14.

Place the arresters on the load side of the service entrance disconnect box.

If emergency power is used and the transfer switch is on the premises, place an additional arrester, with a lower-threshold-of-firing voltage, on the load side of the transfer switch.

**NOTE: This arrangement:**

- Limits any transient introduced by the auxiliary power.
- Keeps the entering service wiring, main disconnect equipment, and commercial side of the transfer switch unprotected unless an arrester is also installed at the power service entrance.

Equip all arresters installed indoors with fuse or breaker protection in case a permanent short in the unit occurs. Alarm the fuses or breakers to signal the trouble condition.

Secondary arresters are available for various service ratings starting at 120 Vac. The arrester rate refers to the rms voltage at which the arrester satisfactorily interrupts power current. The rate does not refer to the arrester's:

- Sparkover voltage.
- Operating potential.

Mount the arrester close to the transfer switch to avoid:

- Long leads.
- Unnecessary bends in the connections.

**NOTE: Arrange with the power company to have the primary circuit arrester ground (the power company's arrester) and the neutral wire of the secondary system interconnected solidly, or through an isolation gap at the commercial power transformer bank serving the radio site.**

### 13.3 Isolation Gap

Some power companies operate their distribution systems with separate grounds for:

- Primary lightning arresters.
- Secondary neutral.

Because of this possibility, discuss with the power company the proper method to provide common bonding at these locations.

**NOTE: Provide a suitable isolation gap or arrester in the bonding path if the power company operating practices or local electrical codes do not permit a solid interconnection. The power company must provide the isolation gap.**

## 13. AC Power Service Protection, continued

---

### 13.4 Bonding to Power

Bond all conduit, armored cables, and switch boxes containing power wires to provide direct, low-resistance paths to ground for surge currents.

### 13.5 Branch Circuit Arresters

Branch circuit arresters are used to protect the branch power circuit for the aircraft warning lights (to the tower). In areas of high lightning incidence:

- Attach a metal lightning rod, extending a minimum of 12 inches (305 mm) above the highest fixture, to the antenna support.
- Bond the rod to the grounding conductor or the metallic antenna support (mast or pole). See Exhibits 6 and 7.
- Use the ground system at the base of the pole or tower as the lightning rod ground.

Bond across expansion joints in the metallic conduit containing the AC wiring to the warning lights to ensure continuity. Bond the metallic conduit to the metallic tower every 10 feet (3 m) through the mounting hardware.

In addition to the power arresters at the main service:

- Provide branch-circuit secondary arresters on circuits feeding power to susceptible equipment such as:
  - Rectifiers.
  - Power supplies.
  - Cable air pressure machines.
  - Well pumps.
  - Other susceptible equipment.
- Mount the secondary branch circuit arrester close to the equipment that it is protecting.

### 13.6 Leased Sites

On sites that GTE Telephone Operations leases from other parties, install or establish, as a minimum, separate (or dedicated) AC branch circuit(s) equipped with a surge arrester before adding equipment to the site.

**NOTE: These branch circuits should feed only GTE owned equipment.**

### 13.7 Reference

For additional supplemental information on grounding of AC Power Entrance facilities, refer to GTE Telephone Operations Practice 795-805-072.

# 14. Transmission Lines

---

## 14.1 General

The transmission line is usually a waveguide sized according to the frequency in use. Occasionally, the transmission line might be a coaxial cable.

## 14.2 Coaxial Transmission Line Grounding

The magnetic field produced by high currents in the outer conductor, or shield, might cause dielectric failure of the coaxial transmission line or waveguide.

Ground all transmission lines, whether coaxial, heliath, or waveguide, to the metallic tower or a pole ground at:

- A point closest to the antenna.
- The entrance to the building.
- Intervals not to exceed 75 feet (22.8 m).

Place a ground strap parallel to the transmission line and in a downward direction toward the tower leg.

**NOTES:** Use GTE **standard ground kits compatible with the type of transmission line used.**

Ground the transmission line support frame (ice bridge) at both ends. Grounding and bonding can be accomplished through the use of appropriate hardware.

## 14.3 Bulkhead Grounding

Bond the exterior of the entrance metallic hatchplate or bulkhead to the waveguide and to any other metal structure, such as a transmission line support frame (ice bridge). Connect directly to the outer grounding system with a lead in a downward direction.

There must be a connection between the waveguide entry point (hatchplate or bulkhead) and the external ring (Lead 1).

Bond the waveguide to both ends of the pipe, if a metal pipe or steel tube is used instead of the hatchplate. The pipe is connected directly to the:

- Exterior ring (Lead 1).
- Interior (Halo) ring (see Exhibit 1).

**NOTE:** **Bond the interior of the entrance hatchplate or bulkhead to the interior (Halo) ring or MGB (whichever is closer).**

## 14.4 Radio Frequency (RF) Surge Suppressors

Use an RF surge suppressor to minimize damage to equipment from surges traveling in the center conductor.

When needed, mount the RF surge suppressors or lightning arresters:

- On the outside of the bulkhead or hatchplate.  
OR
- At the base of the tower before turning toward the building.

**NOTES:** **The RF surge suppressors or lightning arresters should not be located inside the station building or equipment enclosure.**

Connect the RF suppressor's ground lead to the outer ground ring. Do not force the ground lead to negotiate sharp bends around the facility.

# 15. Radio Station Equipment

---

15.1

## General

Grounding and bonding of elements inside and outside 7 radio station site (building or hut):

- Contributes to the safety of the:
  - Installation.
  - Site's personnel.
- Prevents arcing and side flashes.
- Reduces the hazards of fire when lightning does strike the site.

The area near a tower (including building walls, foundations, etc.) increases in voltage potential when the tower is energized due to a lightning strike (either direct or indirect). The equipment frames/racks also have a corresponding increase in voltage potential.

Bonding and grounding alone might not be enough to prevent induced surges on unshielded equipment wiring or cables from causing damage.

**NOTE: Refer to Exhibit 9 for an illustration of protective measures for radio station sites.**

15.2

## Interior Ring Bus System

Provide a ground bus (also called Halo ring or peripheral ground bus) around the interior perimeter of the station building to facilitate common bonding of station equipment and to establish a low impedance path to earth (see Exhibit 19).

Provide bonding connections (Lead 21 B):

- Between the external buried ring (Lead 1) and the peripheral ground ring (Halo ring) at each corner of the building.
- With additional bonds in between if the distance between connection points exceeds 50 feet (15.2 m).

There must be a connection between the waveguide entry point (hatchplate or bulkhead) and the internal ring.

Make all these bonding connections with a minimum of #2 AWG SBTC wire.

**NOTE: The dielectric strength of the radio equipment connected to coaxial transmission lines at fixed stations provides adequate protection against damage from lightning when the protection arrangements for coaxial antennas and coaxial transmission lines are applied.**

The interior ring bus (Lead 21A) system serves as the common ground conductor in the radio room to ground (via Lead 21C) the:

- Relay rack uprights.
- Metallic objects.
- Other equipment.

The interior ring bus system consists of a #2 AWG wire (minimum) either solid or stranded, bare or jacketed, supported on walls at a convenient height typically above the cable rack and supported every 2 feet (610 mm) by non-metallic hardware or as it becomes necessary at corners or turning points. Lead 21A terminates in the P zone of the MGB.

**NOTE: THHN insulation is preferred.**

## 15. Radio Station Equipment, continued

---

### 15.2 Interior Ring Bus System, continued

The interior ring should have a minimum number of bends. The bend radius should be a minimum of 12 inches (305 mm).

**NOTE: Do not use the Halo ring as a battery return ground path.**

### 15.3 Bonding to the Halo Ring

Use #6 AWG conductors to bond the items to the Halo ring. Use two compression fittings between Lead 21 C and the ring (Lead 21 A). After all bonding is completed, all major elements in the radio room that have been grounded should show two paths of equalization. These two grounding paths should be diverting or oriented in opposite directions.

The bonding path length between the metallic objects located in proximity must not exceed:

- 15 feet (4.6 m) if the objects are within 1 foot (305 mm).
- 30 feet (9.1 m) if the objects are within 6 feet (1.8 m).

Provide a supplementary ring or a direct bonding connection, if these conditions cannot be met.

### 15.4 Items to be Bonded to the Halo Ring

Bond all non-IGZ metal elements in the radio equipment room to the peripheral ground ring (Halo ring) via Lead 21C including:

- Waveguide hatchplates or bulkheads.
- Air conditioning/HVAC units and ducts.
- Generator enclosure and support chassis.
- Exhaust vents.
- Vent hoods.
- Fuel tanks.
- Air dryers.
- Metallic door frames.
- Metal pipes.
- Light fixtures.
- Metal cabinets used for spare parts.
- AC power service disconnect and electrical panel enclosures.
- Frames of equipment uprights including:
  - Miscellaneous equipment.
  - MGB.
  - Distribution power panels, chassis, battery racks, frames, and chassis of rectifiers.
  - Cable racks.

**NOTE: Do not bond to fire protection systems.**

Maintain 6 feet (1.8 m) separation between equipment grounded to the Halo ring (Lead 21A) and the IGZ equipment.

## 15. Radio Station Equipment, continued

---

### 15.5 Bending Radius of Halo Ring

Use the following guidelines when making bends in the grounding conductors:

- Decrease the inductance of the interior ring by reducing the number of bends used.
- Make the bends smooth and with the largest radius possible.

**NOTE:** The normal bend radius must be 1 foot (305 mm) or greater. In extreme cases the bend radius could be 6 inches (152 mm) but never less.

### 15.6 Master Ground Bar (MGB)

Tag all leads connected to the MGB, indicating the lead number. If two or more leads have the same lead number, show the "to" and "from" for each lead involved.

### 15.7 Colocated Sites Guidelines

Observe the following guidelines in colocated sites:

- Locate the transmitter/receiver equipment at least 6 feet (1.8 m) away from the:
  - Digital switching equipment.
  - Electronic processor equipment.
- Keep the coaxial and/or waveguide cables separated (1 foot [305 mm] minimum) from:
  - Telephone switching cables.
  - Voice frequency cables.
  - High frequency cables.
  - DC power cables.
- Ground the transmitter/receiver equipment to the interior ground ring (Halo) or MGB via Lead 56.
- Ground the inside of the bulkhead or hatchplate to the Halo ring or to the MGB via Lead 55.
- Provide AC power to all the radio station equipment from a dedicated AC service run and a dedicated circuit breaker.

**NOTE:** Do not share circuit breaker or power cable with other equipment such as data, carrier, and switching equipment.

### 15.8 Internal (Halo) Ground Rings and Colocation

Observe the following guidelines in colocated sites (e.g., sites having radio and switching equipment in the same structure):

- Provide an internal (Halo) ground ring for the entire floor/room if the radio equipment occupies more than 50% of the installation, when the radio station equipment shares floor space with switching and/or transmission equipment in wire center buildings or par gain equipment huts.
- If the radio equipment occupies less than 50% of the floor space, only the area or room dedicated to the radio equipment requires a Halo ring.
- Connect the Halo ring to the MGB via Lead 21.

## 15. Radio Station Equipment, continued

---

- 15.9  
Grounding  
Radio  
Equipment** Ground the metal parts of radio transmitting and receiving equipment using the relay rack mounting arrangement. This method maintains all exposed metal radio equipment parts at the same electrical potential.
- Most radio equipment chassis have ground lugs that must be wired directly to the station ground bus.
- 15.10  
Isolated Ground  
Zone (IGZ)  
Integrity** Maintaining the integrity of the IGZ in COs that have radio equipment colocated with switching equipment is essential. Isolate all IGZ ironwork from non-IGZ ironwork with dielectric materials.
- 15.11  
Leased Sites** On sites that GTE Telephone Operations leases from other parties, install or establish separate (or dedicated) grounding leads for the equipment as required. If non-GTE owned equipment is present in the building or hut, do not share grounding conductors. Common bonding must take place at either the site's MGB or the Halo ring.
- NOTE: Ensure that the MGB and/or Halo are connected to an external grounding electrode (a ground ring is preferred).**
- 15.12  
Reference** For supplementary protection requirements for the other equipment located inside the station building (refer to GTE Telephone Operations Practice 795-805-071).

## 16. Global Positioning System (GPS)

---

- 16.1  
General** The GPS is a satellite-based radio navigation aid designed to provide global, all-weather, precise navigation and timing capability 24 hours a day.
- GPS equipment in use within GTE typically consists of a Timing Antenna/Receiver, a LORAN-C Antenna, and Timing Interfaces. These items, and other associated equipment, are used to establish a Stratum 1 Primary Reference Source for synchronization of digital facilities.
- Refer to the vendor's documentation for specific detailed information.
- 16.2  
GPS Antennas** GPS antennas are designed to be mounted on:
- Metal support structures (towers or poles).
  - Building walls.
  - Building roofs.
- Mount the GPS antennas on an accessible location, away and above from metallic reflective objects and away from other antennas.
- 16.3  
GPS Antenna  
Grounding** Ground all GPS antennas using the methods described in this practice. Roof mounted GPS antennas should have a small roof ground ring around their support base. Connect the roof ring to the building ground ring (Lead 1) via down conductors (Lead 22). If the roof contains other metallic items (such as HVAC equipment) and the GPS antenna is within 10 feet (3 m) the roof ring should include all metal items (see Exhibits 20 and 21).

## 16. Global Positioning Systems, continued

---

### 16.3 GPS Antenna Grounding, continued

Provide a lightning protection system when its need is determined from the Risk Assessment Guidelines of GTE Telephone Operations Practice 887-795-070.

### 16.4 Lightning Arrester

Most vendors recommend the use of lightning surge arresters on the GPS transmission lines. Place these arresters just before the entry point of the transmission lines into the building. Take the arrester ground lead directly to the ground ring (Lead 1). Do **not** place these arresters inside the building.

**NOTE:** It is GTE's policy not to install primary Lightning Protectors, or Lightning Arresters, inside GTE buildings. It has been a long standing GTE policy to install these devices exterior to the buildings to reduce the possibility of damages inside the building.

Some GPS equipment vendor recommends the use of secondary arresters (surge protectors) for use inside the building. Ground these arresters to the nearest ground bar (MGB/FGB).

**NOTE:** Use only the type of arresters that are recommended by the GPS equipment vendor.

## 17. OSP Entrance Facilities

---

### 17.1 General

The telephone entrance facilities to radio stations are subject to foreign potentials and currents from both induction and conduction processes.

### 17.2 Telephone Facilities

For radio stations in urban areas, the antenna arrangements and path for diverting lightning strikes to ground reduces the possibility of damaging currents affecting telephone facilities. However, telephone facilities entering the site must be protected.

At radio stations in rural areas, telephone facilities need additional protection because the incidence of lightning strikes to the antenna is usually higher than in urban areas. Telephone cable serving stations in rural areas typically have small diameter sheaths. Therefore, these cables:

- Are more susceptible to damage from lightning currents.
- Have relatively high longitudinal resistance.
- Can develop high sheath-to-pair voltages with low lightning currents on the sheath. Such voltages can damage the cable to an extent that the cable might need to be replaced.

## 17. OSP Entrance Facilities, continued

---

### 17.3 Cable Shields

The shields of all cables entering a radio station must be:

- Bonded.
- Grounded to the site's grounding system.

When metallic entrance conduits are used, the conduits must be:

- Bonded.
- Connected to the site's grounding system using a #6 AWG insulated, tinned copper wire.
- Bonded to the shields of the cables inside the conduit at each end of the conduit.

### 17.4 Telephone Service Protection

Radio station sites having telephone service provided should have the protector, NID, PTD, and BET properly grounded with direct and straight connections to the site's grounding system.

**NOTE: If the BET or PTD is inside the building or hut, connect the ground terminal to the MGB via a direct and shortest possible route.**

### 17.5 Protection

The following chart shows that protector blocks placed at the site between all conductors and the cable sheath (which is bonded to the site's grounding system) reduces high core-to-sheath voltages.

---

<b>if the Cable Serving a Small Radio Site Is...</b>	<b>Then Full Count Protection...</b>
A small branch from a larger cable	On the branch cable at the junction to the larger cable tends to reduce core-to-sheath voltages that might develop away from the radio station toward the larger cable.
In an area where a high incidence of lightning occurs	Suitably spaced at different intervals on both the small branch and the large cable might be considered to reduce core-to-sheath voltages.

---

**NOTE: Protected terminals used with facilities serving radio sites must have protectors (either gas tubes or solid-state modules).**

### 17.6 Cable Shield Voltages

The voltage value developed for a given shield current depends on:

- Shield conductivity.
- Spacing between protectors.

These voltages might become high enough to cause dielectric failure in paper- or pulp-insulated conductor cables. Full count protection at shorter intervals might be necessary.

**NOTE: Use polyethylene-insulated conductor cables for this application.**

## 17. OSP Entrance Facilities, continued

---

### 17.7 Entrance Cable

Where communication circuits enter radio sites by cable, at least 6 feet (1.8 m) of the entrance cable must:

- Be 24-gauge wire.
- Terminate inside the building in an interior terminal box (BET or PTD) equipped with protectors.

**NOTE: All pairs entering the radio building or hut MUST be terminated on protectors.**

Use conduits from outside the entry wall to the tip splice of the protector; otherwise, wrap the cable inside the building with approved fireproofing tape.

If the cable is buried and has a metallic outer shield, bond the shield to the ground ring at the point where they cross or are the closest. The bonding wire should be as short as possible.

#### **17.7.1 Aerial Cable Entrance**

Aerial entrance facilities must have the cable shield and the strand bonded and grounded at the last pole before the entry point. Bond to the MGN, if present.

If the support strand, or messenger, is attached at the building, bond it to the ground ring (Lead 1).

Terminate all pairs (working and non-working) entering the building on protectors.

#### **17.7.2 Buried Cable Entrance**

Buried entrance facilities must have the cable shield bonded and grounded at the last pedestal before the entry point. Bond to the MGN if present.

Terminate all pairs (working and non-working) entering the building on protectors.

### 17.8 Other Circuits

Protect other types of cables (such as video pairs and coaxial cables) that provide circuits to the radio site. The metallic members of these cables must be:

- Bonded at the first point of access as they enter the building.
- Common bonded to the site's grounding system.

Protect these circuits against foreign voltages. The grounding conductors of these protective devices must be common to the site's grounding system.

### 17.9 Insulating Joints

Where an insulating joint is placed in the entrance cable to mitigate electrolysis, install a capacitor across the joint to reduce noise. Keep the leads of this capacitor as short as possible.

**NOTE: Refer to GTE Telephone Operations Practices 605-I 00-201 and 633-405-200 for additional information on insulating joints.**

## 17. OSP Entrance Facilities, continued

---

17.10

**Radio**

**Frequency (RF)  
Shielding**

Shield the telephone facilities to avoid or minimize RF interferences. This shielding should consist of the following:

- Protectors and building terminals should be in a grounded metal enclosure.
- Punch blocks (Type 66) should be inside a grounded metal enclosure.

Severe cases of interference might require:

- The installation of copper wire meshes embedded in the walls.  
AND
- Their bonding to the building steel.

17.11

**Wire Facilities**

If the site is sewed with open wire, there is little chance of damage to the wire itself; however, the wire provides a good path for lightning surges that could cause trouble in the entrance facilities.

GTE **does not** recommend serving radio or microwave sites with open wire or unshielded wire due to the additional cost of protective measures.

**NOTE: Existing sites fed with wire facilities might remain "as is" until such time as additional facilities need to be placed. Then upgrade the serving facilities to use shielded cables.**

## 18. Lightning Considerations

---

18.1

**General**

In general, metallic antennas are not damaged by a direct lightning strike but they should be connected electrically to the metal supporting structure to eliminate arcing.

Nonmetallic antennas, such as those made of fiberglass, are susceptible to damage from direct strikes of lightning.

18.2

**Probability of  
Lightning**

An antenna on the roof of a building does not significantly increase the probability of lightning striking the building.

The antenna structure is a prime target for lightning. It constitutes an excellent transmission path for conducting high currents into the equipment or building.

18.3

**Lead 25**

Use Lead 25, a #2 AWG SBTC conductor, to connect the ground rod(s) where Lead 22 terminates to the outer grounding system (Lead 1). Connect Lead 25 exothermically to the ground rods for Lead 22 and via mechanical connectors to Lead 1 (use a hand hole). See Exhibit 17.

18.4

**Lead 26**

Use Lead 26 with a lightning protection system to bond metal objects within 6 feet (1.8 m) of Lead 22. Connect Lead 26, typically a #6 AWG SBTC conductor, exothermically to Lead 22. See Exhibit 18.

18.5

**Lightning  
Protection**

Use the Risk Assessment Guidelines (refer to GTE Telephone Operations Practice 887-795-070) to determine the need for an LPS.

# 19. Inspections

---

## 19.1 Reference

Use Central Office Grounding and Inspection, Form 900C!528, to document all inspections to verify grounding and electrical protection of radio sites (refer to GTE Telephone Operations Practice 795805074).

For maintenance inspection frequency and reporting, refer to GTE Telephone Operations Practice 220-390-001.

## 19.2 Warning Tags

Attach warning tags to water pipes at the point where the grounding conductor is connected to the pipe (see PSB 0131). The tag should warn against removing the connection or bonds without first notifying GTE.

## 19.3 Identification Tags

Affix identification tags or labels with nonmetallic straps to:

- Each lead attached to the MGB.  
OR
- Any other ground bar.

## 19.4 Reports

Complete the appropriate inspection reports as described in Section 18.1 and include the:

- Completion date.
- Ground resistance measurements taken at the time of installation.

**NOTE: This information (refer to GTE Telephone Operations Practices 795-805-074 and 887-600-072):**

- Is needed for comparing ground resistance measurements.
- Must be made annually.

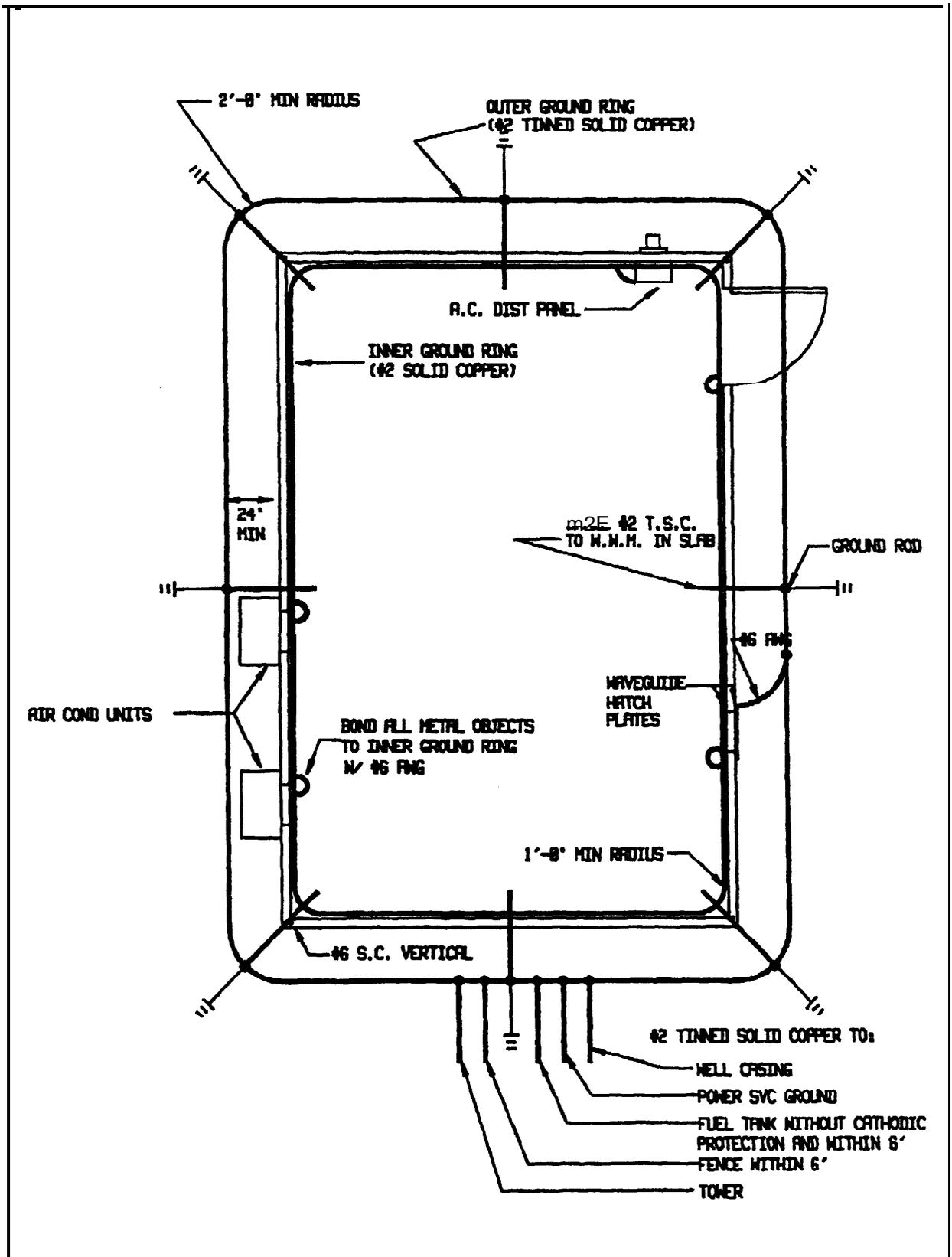


Exhibit 1 - Radio Station Grounding Floor Plan

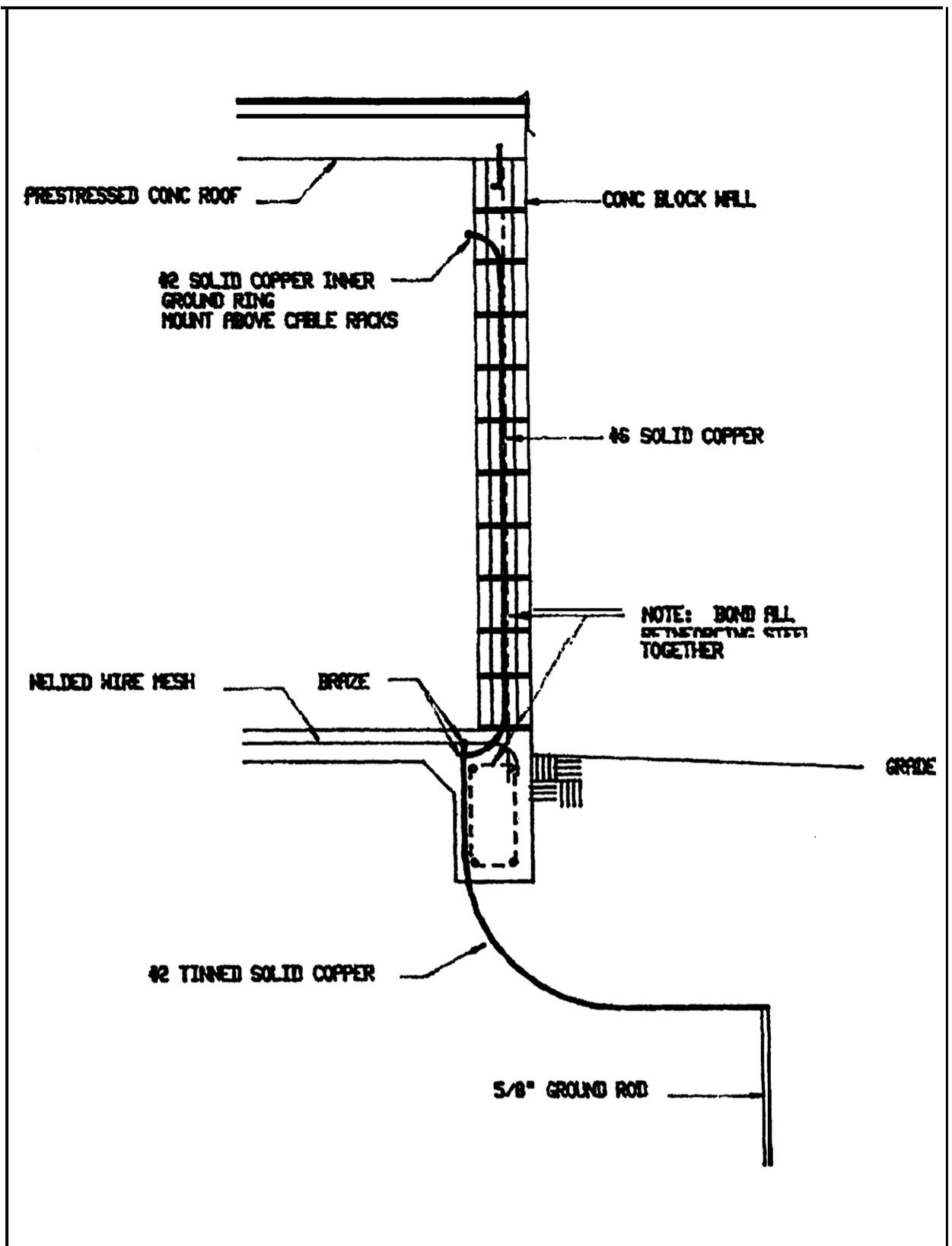


Exhibit 2 - Radio Station Grounding Typical Wall Section

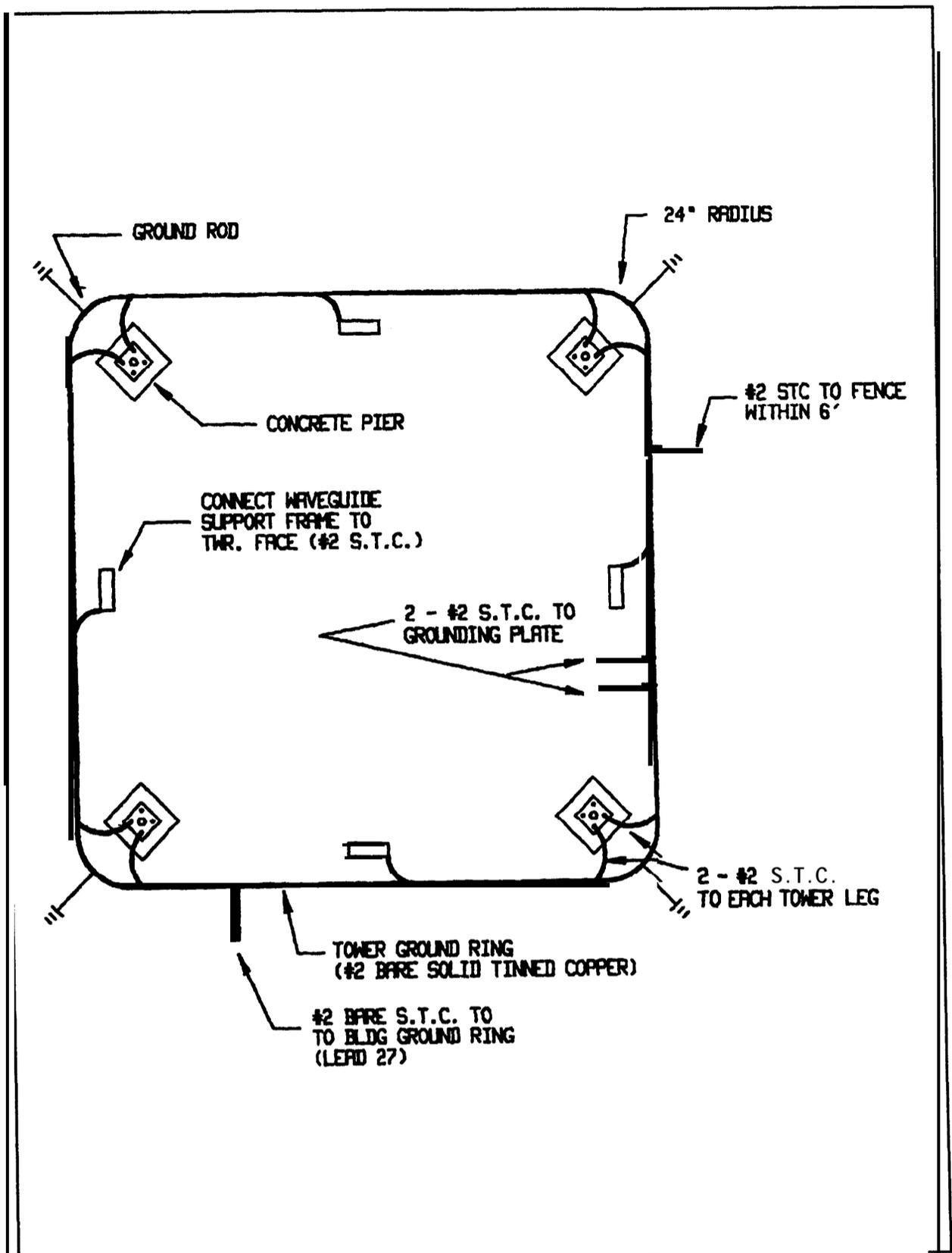


Exhibit 3 - Radio Station Grounding Self-Supporting Tower Plan

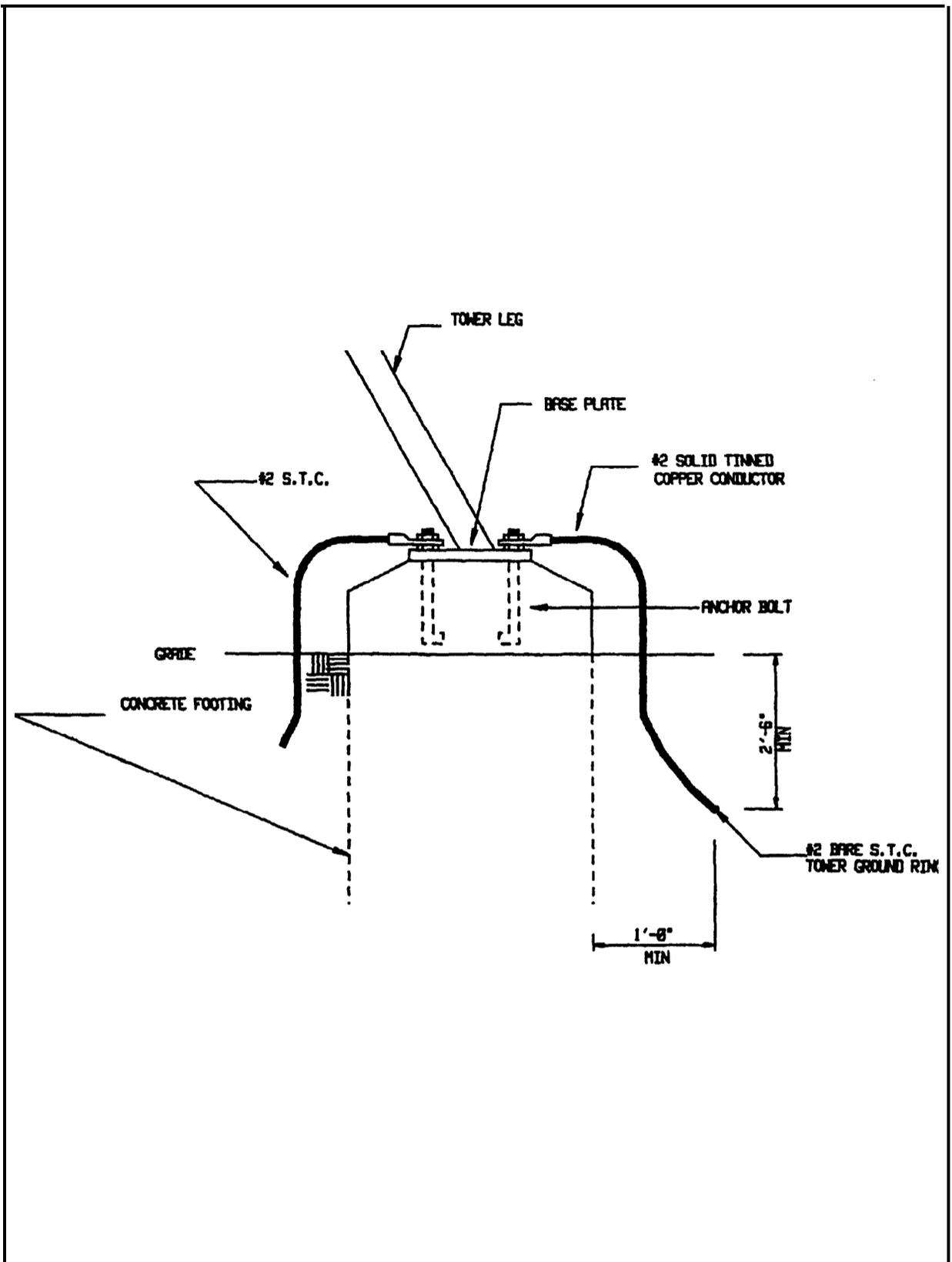


Exhibit 4 - Radio Station Grounding Self-Supporting Tower Footing Detail

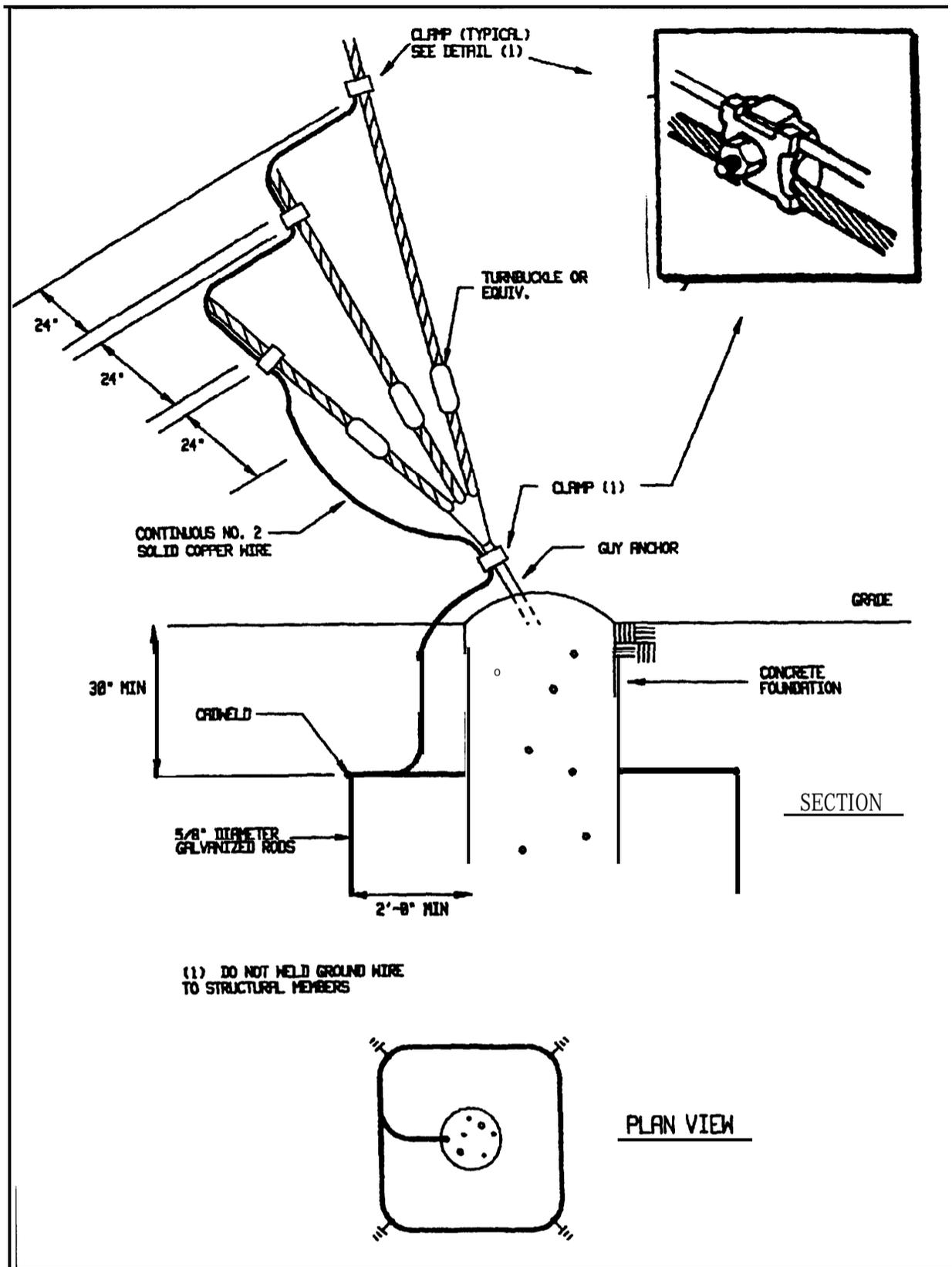


Exhibit 5 - Guyed Tower Guy Anchor Detail

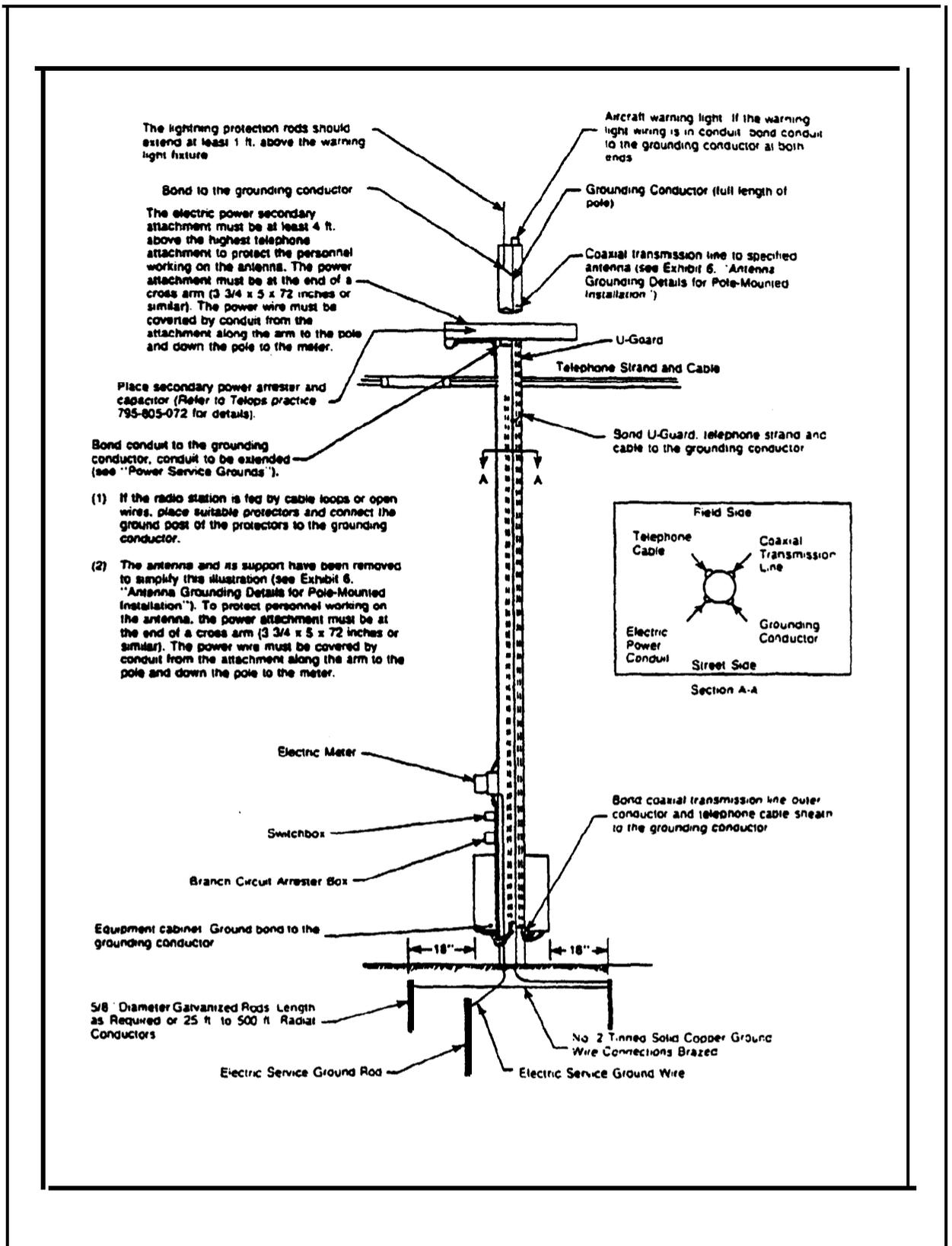


Exhibit 6 - Standard Grounding Arrangement - Typical Pole-Mounted Installation

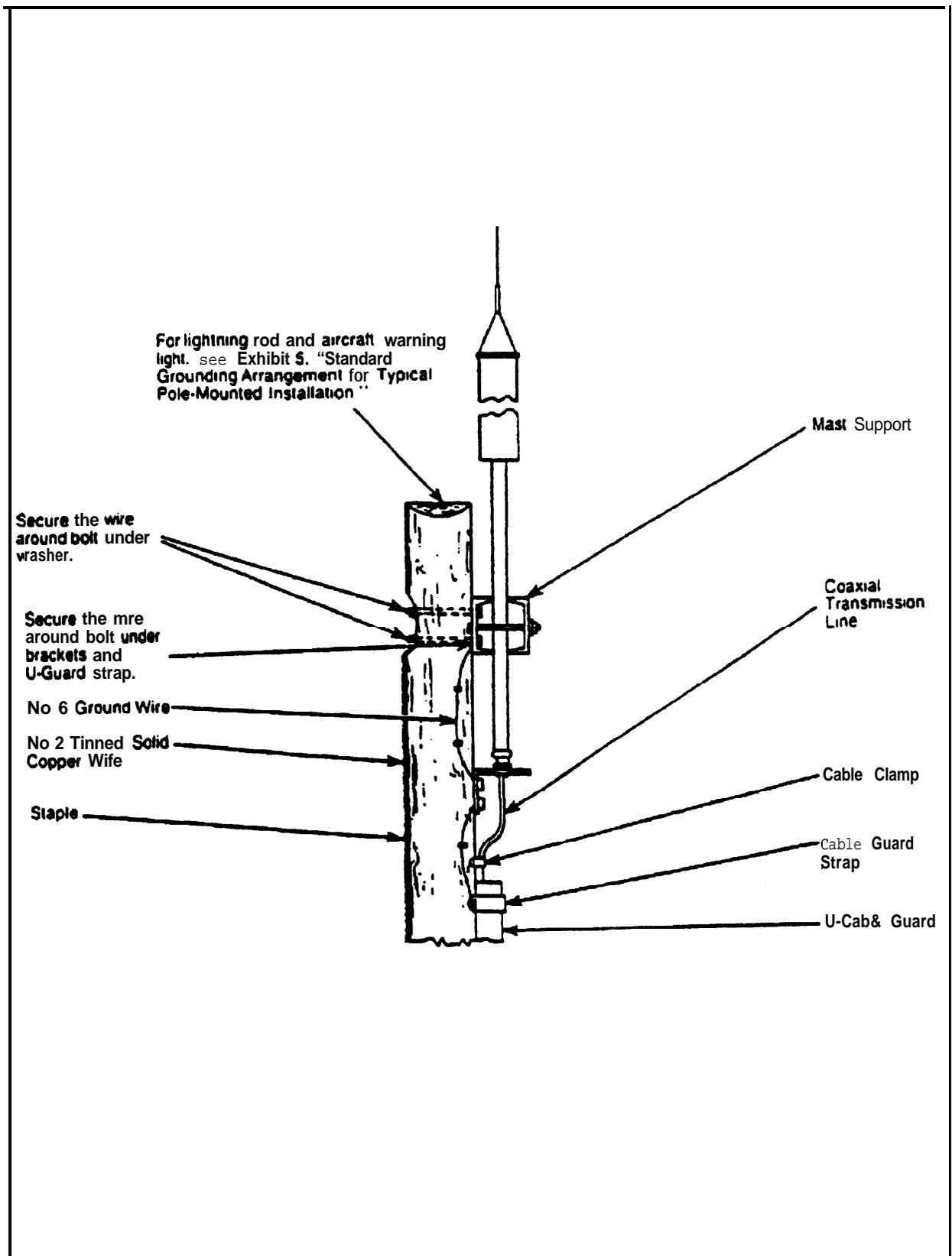


Exhibit 7 - Antenna Grounding Details for Pole-Mounted Installation Sizes

# Exhibits, continued

Lead No.	For	From	To	AWG STD	Notes
1	Bldg	Ground ring and rods	----	2	SBTC
1A	Bldg	Ground ring concrete encased electrodes	----	2	SBTC
2	Bldg	Wells or deep anodes	----	Steel pipe	
3	Bldg	Lead 1 column	Each bldg	2	SBTC
4	Bldg	Main AC enclosure neutral bus	Grounding electrode	----	See Notes 1 and 3
5	Bldg	Lead 1 Min. 2 Lead 5 opposite sides	MGB	Note 3	SBTC
6	Bldg	Lead 1	Metallic fence	2	Metallic fence/posts
7	Bldg	Each Lead 2	MGB	Note 3	SBTC
8	Bldg	Main AC enclosure neutral bus. See Note 1.	Interior of water meter.	Note 3	SBTC

**NOTES:**

1. Refer to GTE Telephone Operations Practice 795-805-072.
2. Refer to NFPA-780 Lightning Protection Code.
3. Refer to GTE Telephone Operations Practice 795-805-071.

(continued)

**Exhibit 8 - Standard Lead Designations and Grounding Conductor Sizes (Page 1 of 5)**

# Exhibits, continued

Lead No.	For	From	To	AWG STD	Notes
9	Bldg	Exterior water pipe	Interior water pipe	Note 3	SBTC
10	Bldg	Interior water pipe	MGB	Note 3	Insulated copper
13	Bldg	Main AC enclosure neutral bus	MGB	Note 1	Insulated copper
14C	Bldg	MGB/FGB	Interior metallic roof or metal skin	1/0	Insulated copper
20	Bldg	MGB or FGB on each floor	Branch AC enclosure on same floor (green wire) ground, not neutral	6	Insulated copper. Not required if there is only one panel.
20A	Bldg	MGB or FGB on each floor	Disconnect enclosure on same floor neutral bus for step-down transformer or separately derived source.	Note 3	Insulated copper
21	Bldg	MGB/FGB	Radio room ground ring (halo). Lead 21A.	2	Insulated copper

(continued)

## Exhibit 8 - Standard Lead Designations and Grounding Conductor Sizes (Page 2 of 5)

## Exhibits, continued

Lead No.	For	From	To	AWG STD	Notes
21A	Bldg	interior (halo) ring	----	2	Insulated copper
21B	Bldg	Lead 21 A	Lead 1	2	Insulated copper
21C	COEC	Lead 21A	Equipment	6	Insulated copper
22	Bldg	Roof radio tower ground ring or and building mechanical equipment	Corner bldg cols lightning rod system	Note 2	Insulated copper (min. 4 Leads per NFPA)
25	Bldg	Lead 1	Nearest lightning rod	2	Insulated copper
26	Bldg	Lightning rod system	All nearby objects-all floors	NFPA 780	Per NFPA 780
27	Bldg	Lead 1	External radio tower ground ring	2	SBTC. See Note 3 for required access points.
28	Bldg	Lead 1	External radio building ground ring	2	SBTC. See Note 3 for required access points.
29	COEE; COEC	Branch AC enclosure (green wire) ground, not neutral	Battery charger frame	Note 3	Green insulated copper in AC conduit

(continued)

### Exhibit 8 - Standard Lead Designations and Grounding Conductor Sizes (Page 3 of 5)

## Exhibits, continued

Lead No.	For	From	To	AWG STD	Notes
30	Bldg; COEC	Branch AC enclosure non-isolated green wire) ground, not neutral	AC outlets (brown)	Note 3	Green insulated copper in AC conduit
31	COEE	MGB/FGB (same floor)	Leads 32-36 and/or modular power board	2/0	Insulated copper
32	COEC	Lead 31	Battery charger frame or shelf	6	Insulated copper. Must terminate at Lead 29 punching.
33	COEC	Lead 31	Battery rack frame	6	Insulated copper
34	COEC	Lead 31	PCU frame	6	Insulated copper
35	COEC	Lead 31	DSU frame	6	Insulated copper
36	COEC	Lead 31	PDU frame	6	Insulated copper
37	COEE	MGB/FGB (same floor)	Battery positive ground	Note 3	Insulated copper
45	Bldg	Main AC enclosure neutral	Branch AC enclosure (separate Lead 46)	Note 3	See GTE Telephone Operations Practice 795805072.

(continued)

### Exhibit 8 - Standard Lead Designations and Grounding Conductor Sizes (Page 4 of 5)

## Exhibits, continued

Lead No.	For	From	To	AWG STD	Notes
46	Bldg; COEC	Branch AC enclosure (separate isolated Lead 45, not neutral	Dedicated AC outlets (orange) (green wire) ground	Note 3	See GTE Telephone Operations Practice 795-805-072.
55	COEE	Waveguide or coax bulkhead	MGB	6	Insulated copper
56	COEE	Station equipment enclosure	Battery charger frame or shelf	6	Insulated copper

**Exhibit 8 - Standard Lead Designations and Grounding Conductor Sizes (Page 5 of 5)**

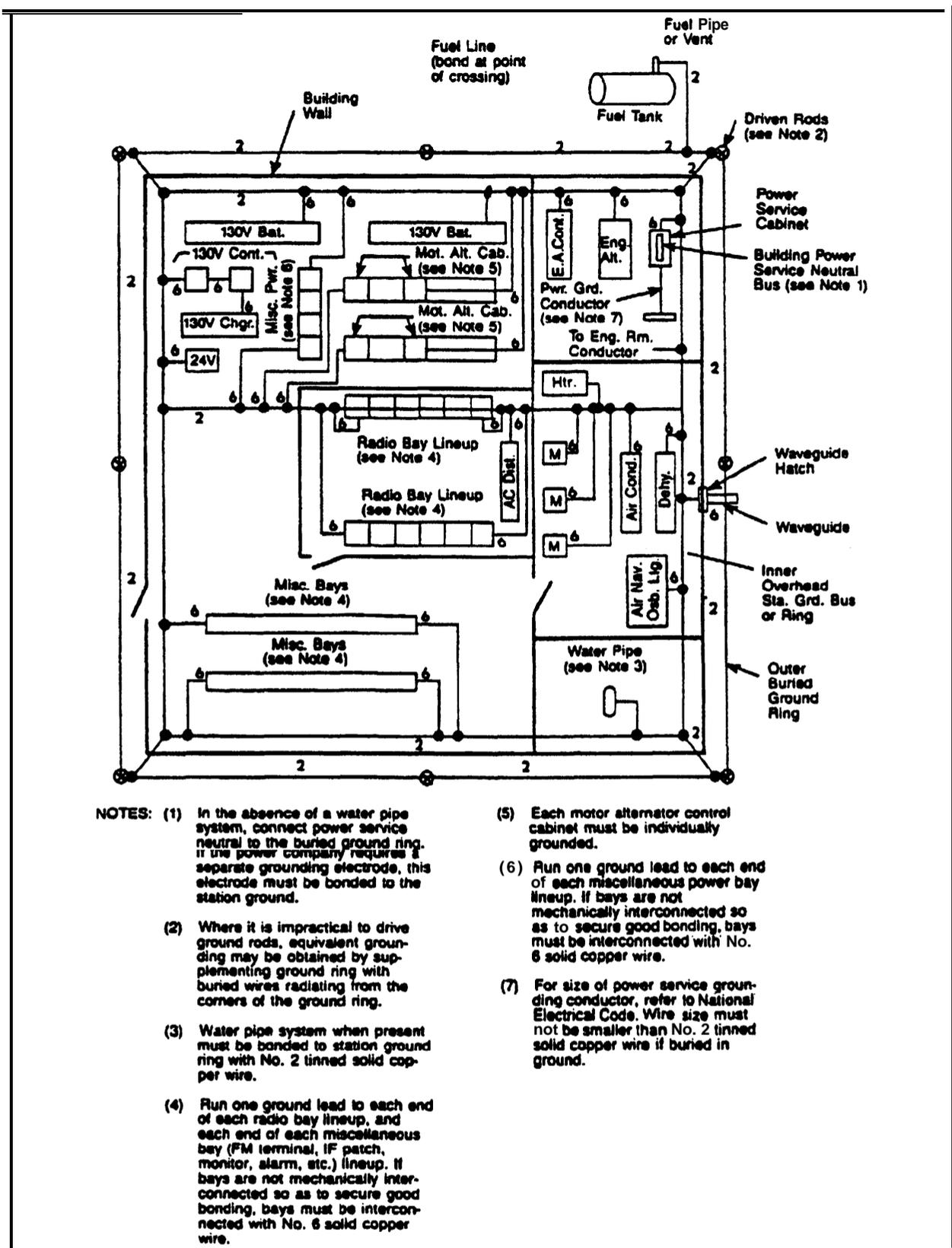


Exhibit 9 - Standard Grounding Arrangement -Typical Large Microwave Repeater Building

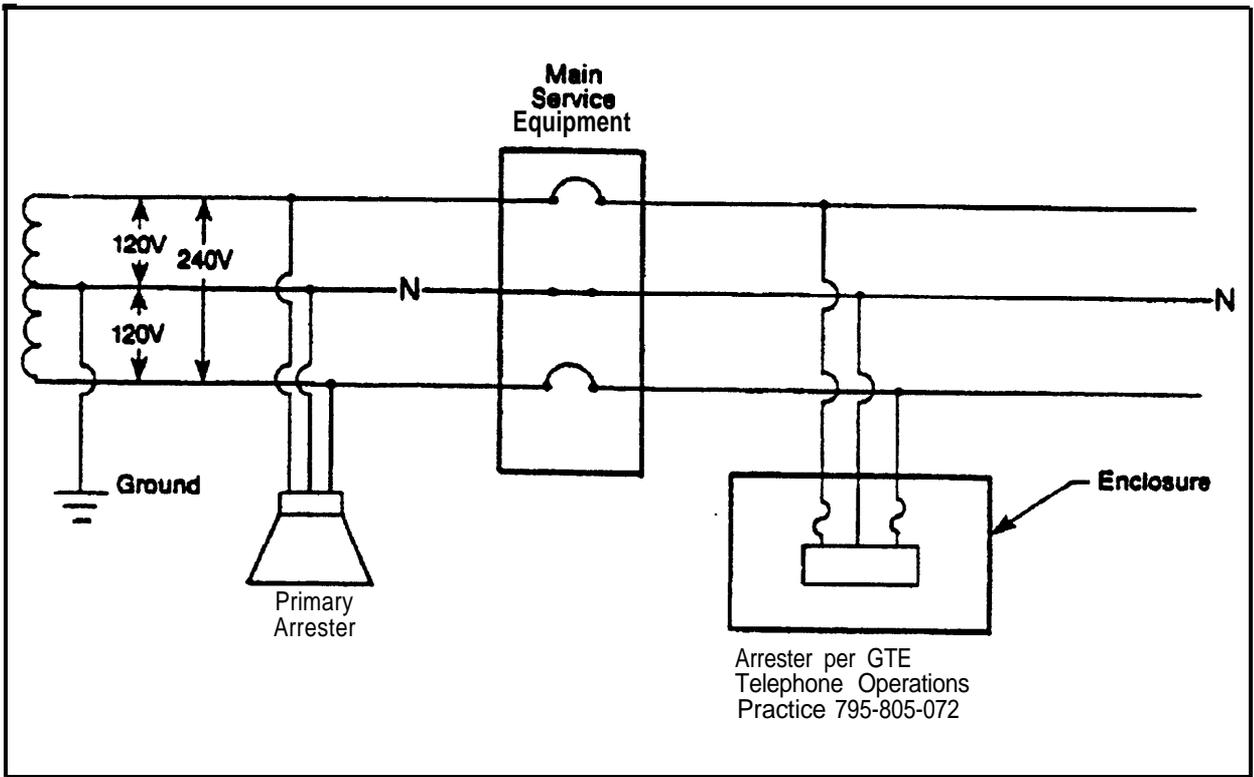


Exhibit 10 - 120V/240V AC, One Phase, Three-Wire, Grounded Neutral Service

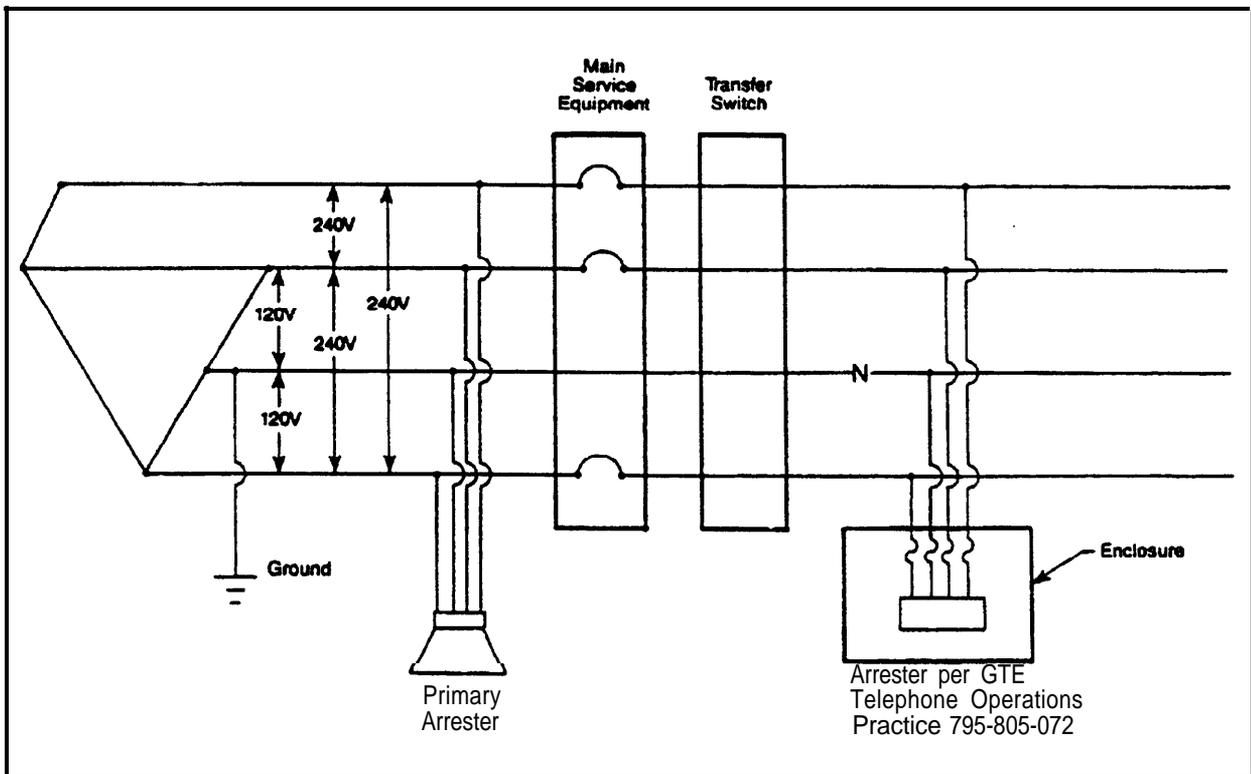


Exhibit 11 - 120V/240V AC, Three Phase, Four-Wire, Center Tap in One Phase, Delta Service

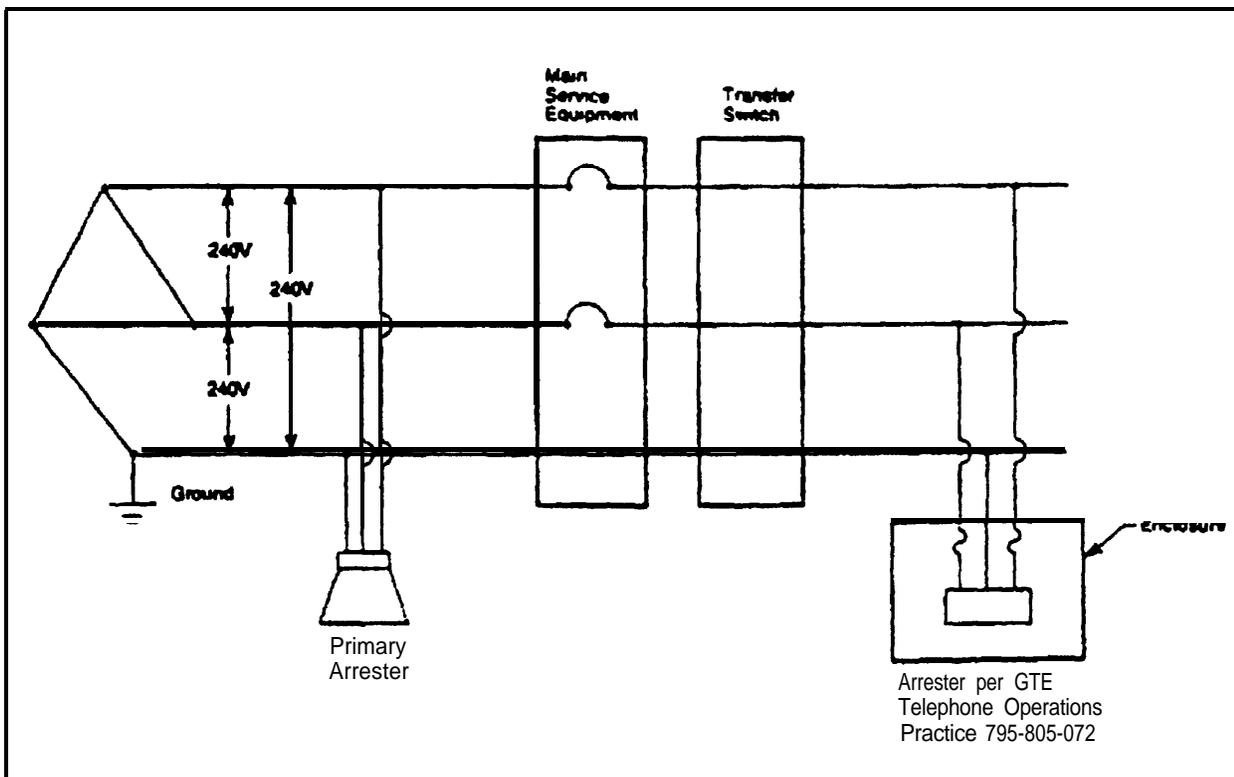


Exhibit 12 - 240V AC, Three Phase, Three-Wire, Corner Grounded Delta Service

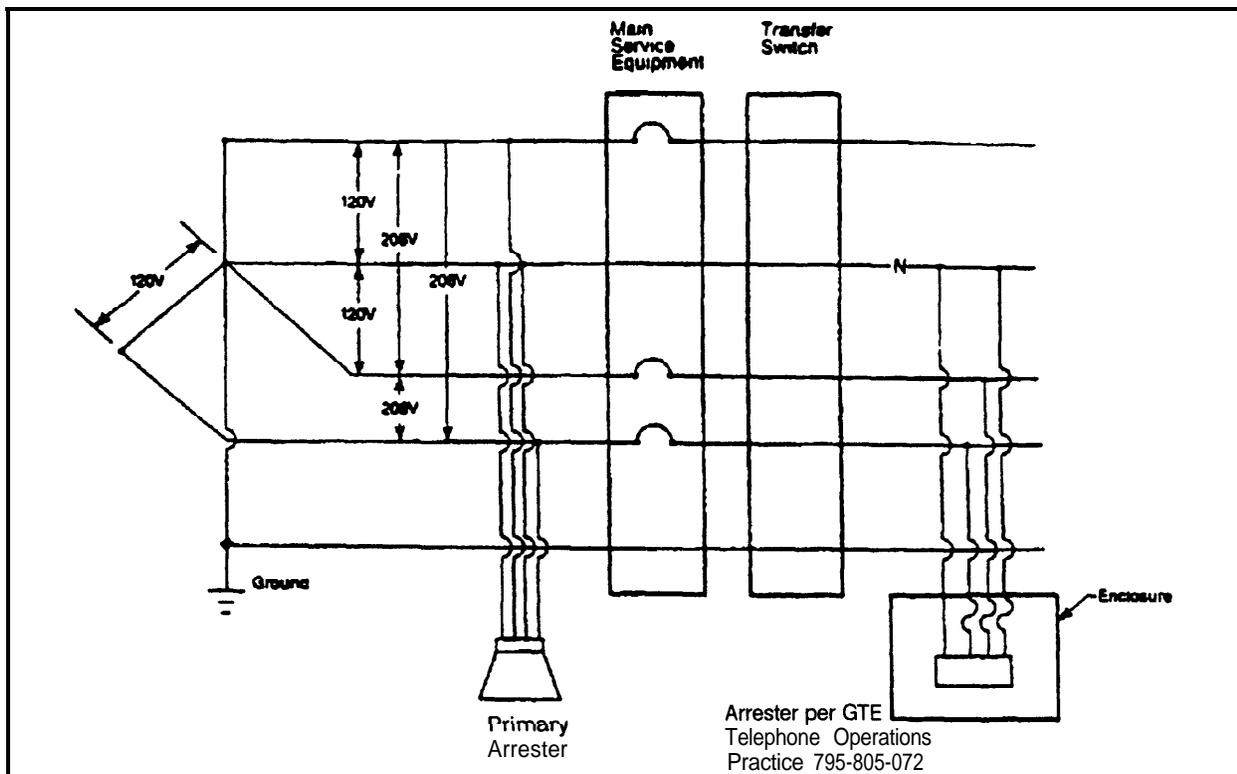


Exhibit 13 - 120V/208V AC, Three Phase, Four-Wire, Grounded Wye Service

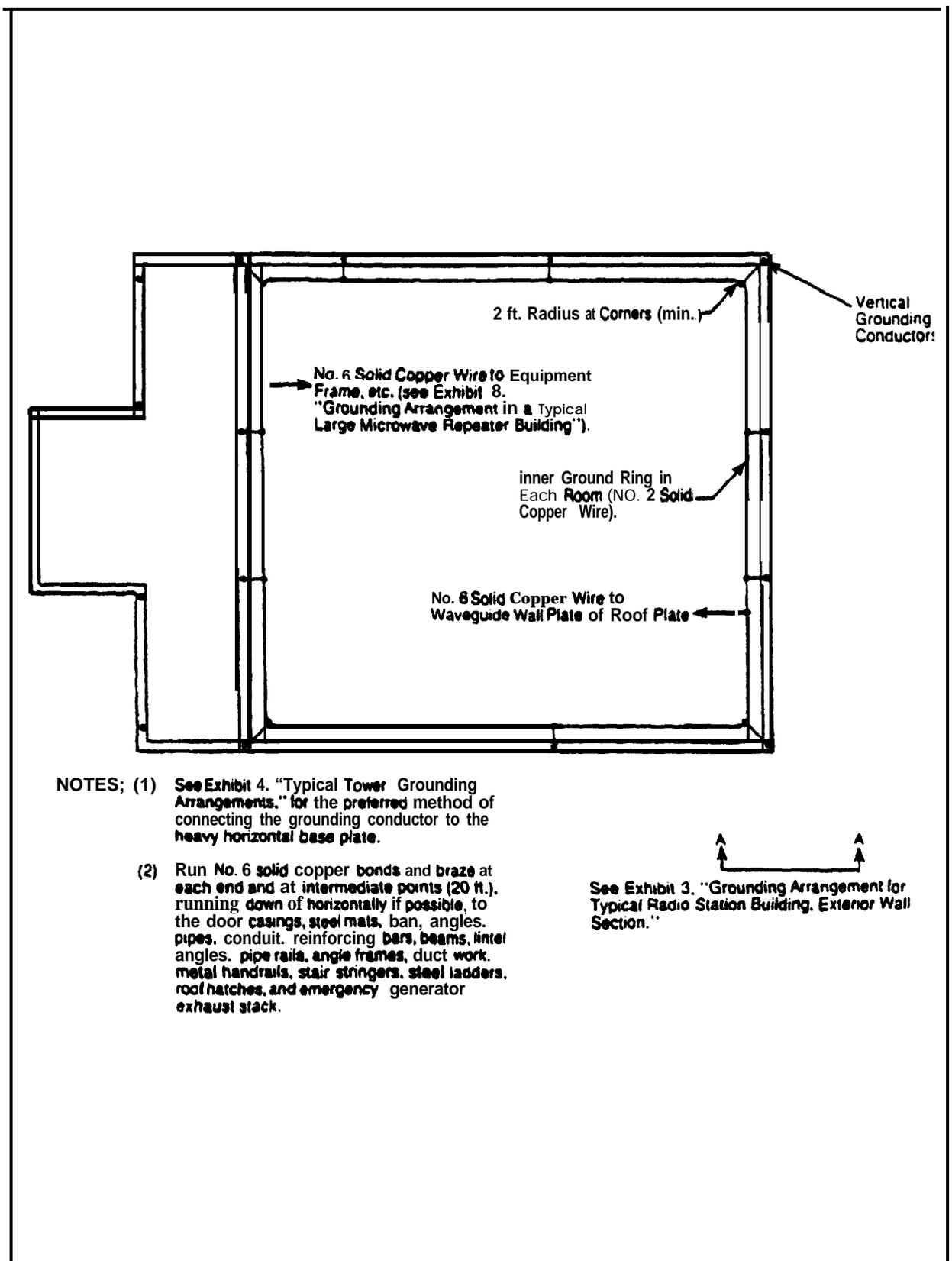


Exhibit 14 - Standard Internal Grounding Arrangement -Typical Fixed Radio Station Building

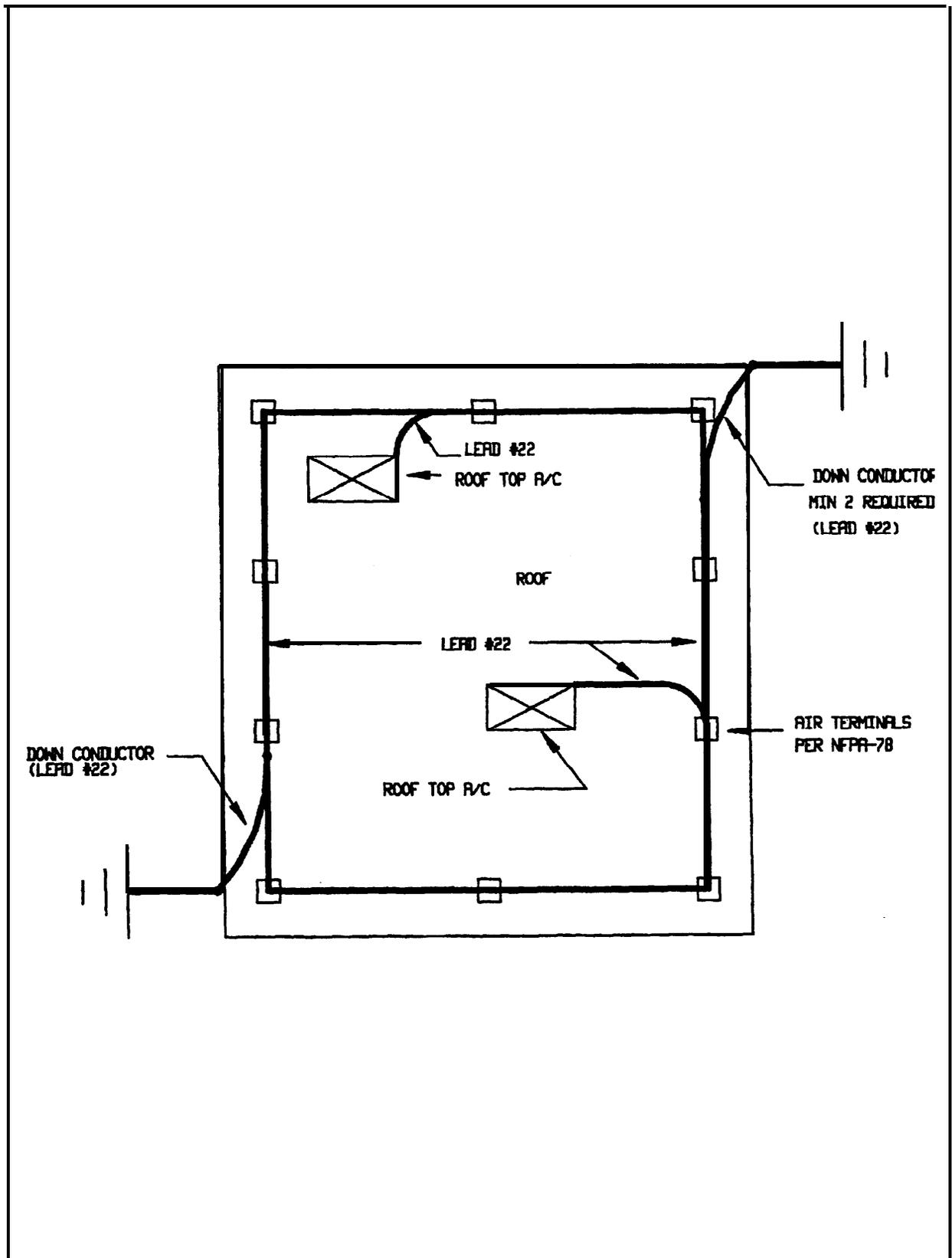


Exhibit 15 - Lead #22 Lightning Protection System

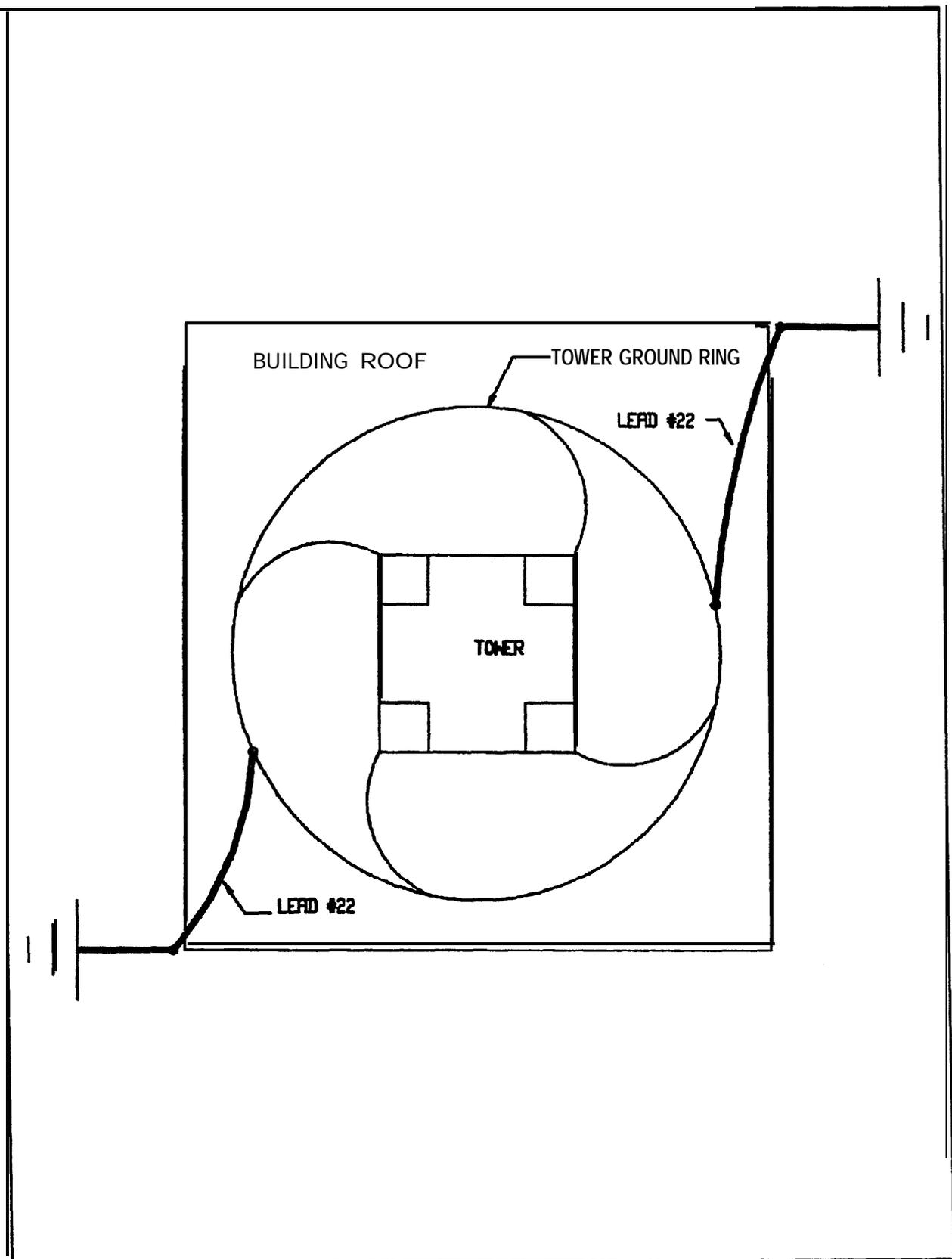


Exhibit 16 - Lead #22 Roof Tower

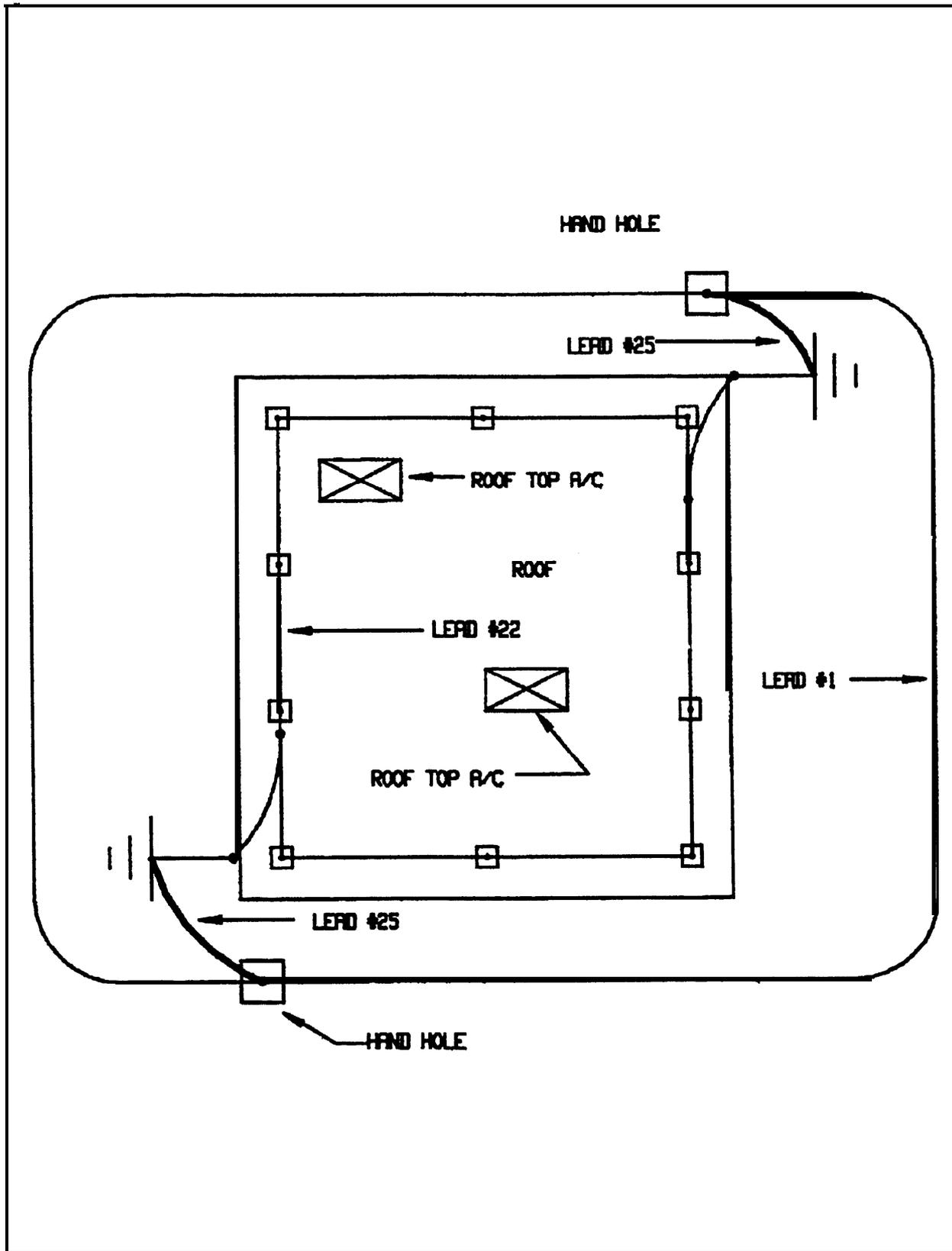


Exhibit 17 - Lead #25 Connection of Lightning Protection System

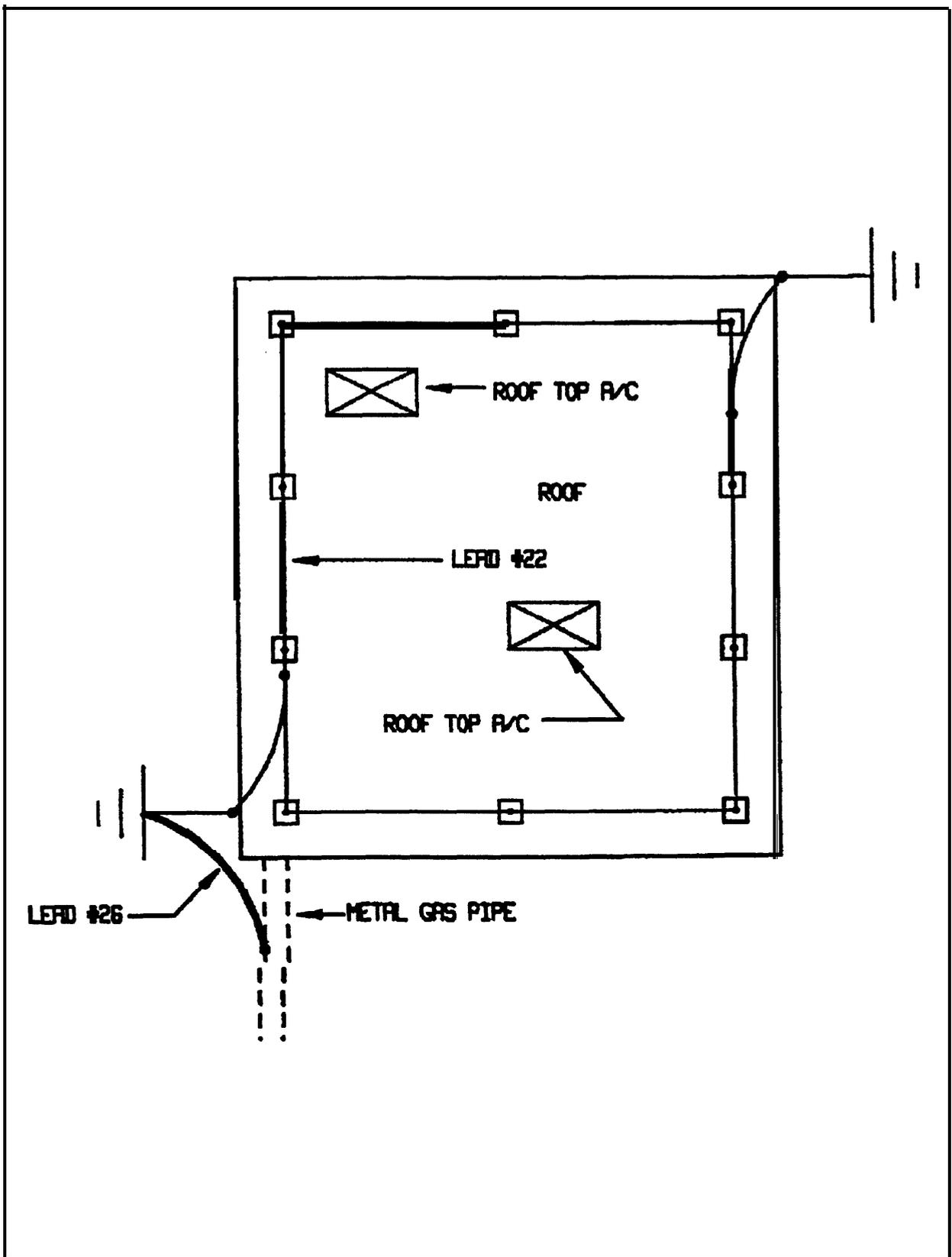


Exhibit 18 - Lead #26 Bonding of Metal Objects

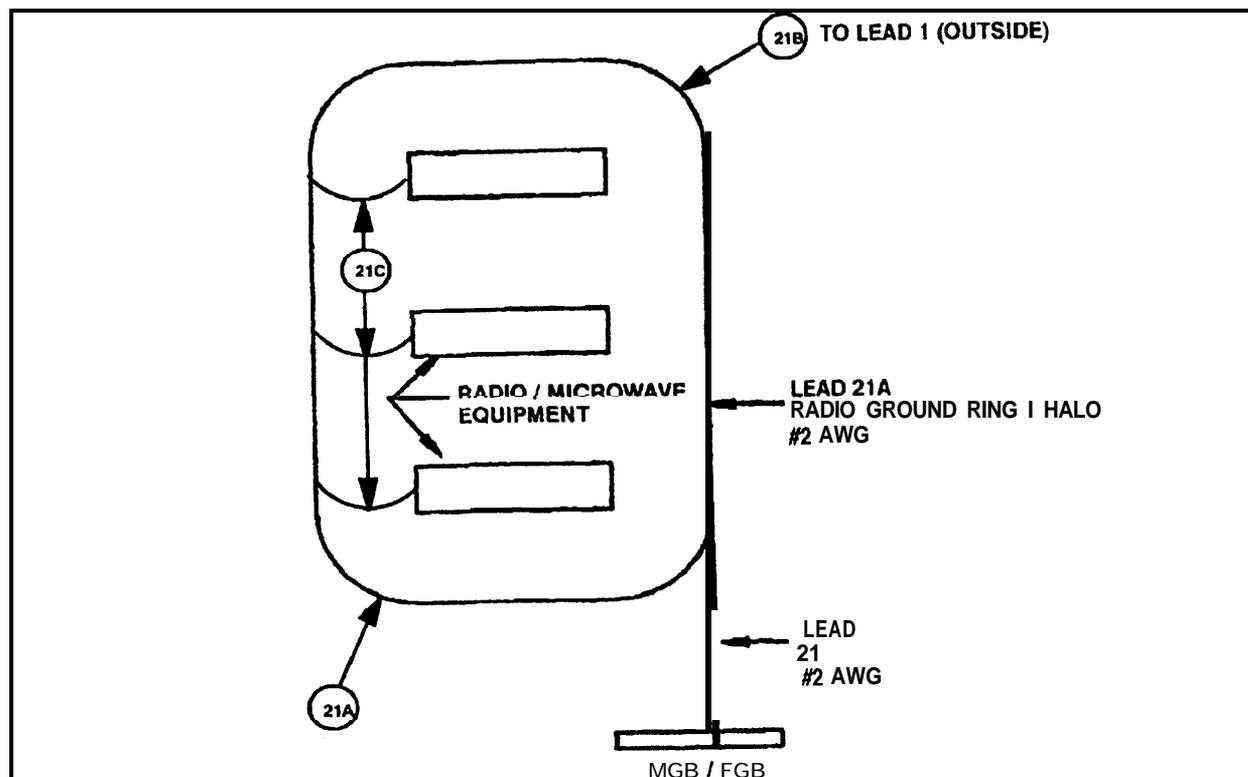


Exhibit 19 - Lead #21 Interior Radio Ground Ring Connection

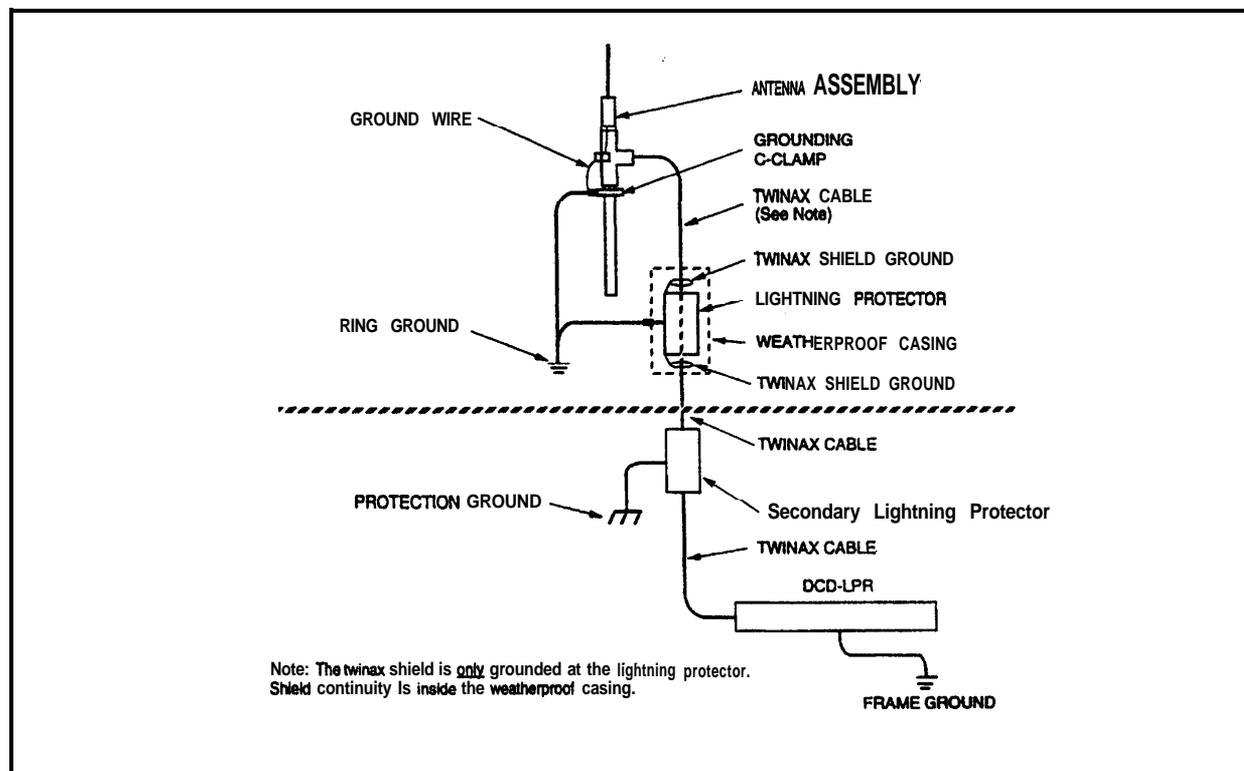


Exhibit 20 - Typical LORAN-C Antenna Grounding Scheme

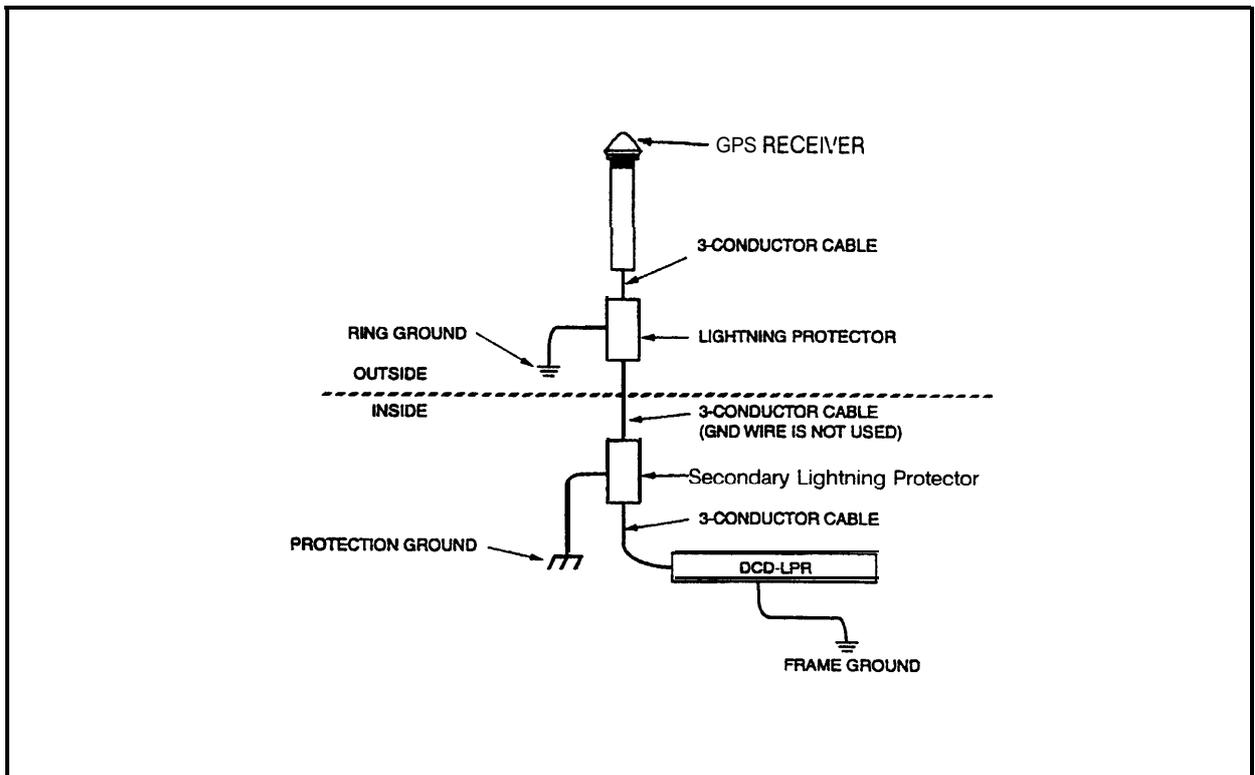


Exhibit 21 - Typical GPS Antenna Grounding Scheme