U.S. Department of the Interior
Bureau of Land Management

RI CASHE Program

Standard Land Mobile Radio Facility Design

Crosswalk Document

February 28, 2013

Produced by Mindbank Consulting Group, LLC

Under contract to Aarcher, Inc.

Tower Designs provided by Aero Solutions, LLC

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Table of Contents

Introduction
- Navigation Tools
- RI CASHE Web-Based Discussions
- Key Personnel
- Purpose of the Standard Radio Facility Design
- Radio Facility Design Scope of Work
- Radio Facility Design Standards
- Typical Radio Facility Designs
- Third Party Testing and Inspection Requirements
- Standard Radio Facility Design Contacts

Reference Tables
- Facility Component Crosswalk Table
- External Grounding Crosswalk Table
- Internal Grounding Crosswalk Table
- Electrical Crosswalk Table

Radio Facility Designs
- Specifications Format
- Specifications Outlines
- Radio Facility Design Inclusions/Exclusions
- Radio Facility Typical Design Drawings and Workbooks
- Conceptual Design
- Radio Facility Candidate Search
- Preliminary Civil Design
- Preliminary Communications Equipment Shelter Design
- Preliminary Tower Design – Obstruction Evaluation
- Final Design of a Radio Facility

Prefabricated Shelter
- Typical Shelter – Design Variables
- Typical Shelter – Selection Considerations
- Typical Shelter – Devices
- Typical Shelter – Delivery Considerations
- Typical Shelter – Design Options
- Typical Shelter – Lighting
- Typical Shelter – Air Conditioner Design
- Typical 8-foot wide, 12-foot long shelter
- Drawing Files for an 8-foot wide, 12-foot long shelter

Prefabricated Shelter (cont.)
- Typical 8-foot wide, 16-foot long shelter
- Drawing Files for an 8-foot wide, 16-foot long shelter

Tower Designs
- Minimum Tower Design Requirements
- Example Tower Designs
- Tower Design Standards
- Tower Design – Classification
- Tower Design – Exposure Categories
- Tower Design – Topographic Categories
- Typical Tower Design Assumptions
- Typical Tower Design Loading Criteria
- Tower Foundation Design Requirements
- Typical Self-Supporting Tower – Antenna Loading Assumptions
- Typical SST – 40-foot Designed for Growth to 60-Foot
- Typical SST – 60-foot Designed for Growth to 80-Foot
- Typical Self-Supporting Tower Assemblies
- Typical Self-Supporting Tower Foundations
- Typical Flanged Monopole – Antenna Loading Assumptions
- **Typical Monopole – 40-foot Designed for Growth to 60-Foot**
- Typical Monopole – 60-foot Designed for Growth to 80-Foot
- Typical Flanged Monopole Tower Assemblies
- Typical Flanged Monopole Tower Foundation
- Antenna Installation – Man-rated Standoff Brackets
- Existing Tower Design Requirements

Aluminum Shelter with Articulating Antenna Mast
- Aluminum Shelter – Design Variables
- Typical 8-foot wide, 12-foot long Aluminum Shelter
- Typical 8-foot wide, 16-foot long Aluminum Shelter

Outdoor Equipment Cabinet
- Outdoor Equipment Cabinet with 15-foot Pipe-Mast
- Outdoor Equipment Cabinet Grounding Design

Fiberglass Shelter with Antenna Radome
- Fiberglass Shelter With Antenna Radome – Design
- Fiberglass Shelter With Antenna Radome – Grounding Design

External Grounding
- External Grounding System Requirements
- External Ground Ring – Installation Requirements
- Grounding Metallic Ancillary Devices
- Tower Ground Bus Bar (TGB)
- External Ground Bus Bar (EGB)

Internal Grounding
- Internal Shelter Grounding System
- Internal Grounding System – Typical Design Drawing
- Master Ground Bus Bar
- copper-integrated Entry Panel
- Bonding Equipment to the Internal Grounding System

Commercial Electrical Power
- Commercial Electrical Power – Service
- Commercial Electrical Power – Service-Disconnect
- Commercial Electrical Power – Surge Protection
- Commercial Electrical Power – Panel Boards
- Commercial Electrical Power – Distribution

Backup Battery Systems
- Battery Installation
- Battery Backup System Components
- Battery Backup System Design
- Typical Battery Backup System Drawings

Photovoltaic Electrical Power
- Photovoltaic Electrical Power – Designs
- Battery Storage Systems on Photovoltaic Powered Facilities
- Battery Storage System Designs
- Battery Installation
- Typical Component Power Consumption
- Budgetary Photovoltaic Calculation Assumptions
- Example 20 to 30-Ampere Photovoltaic System Calculations
- Example 30-Ampere Photovoltaic System Drawing
- Example 30 to 60-Ampere Photovoltaic System Calculations
- Example 60-Ampere Photovoltaic System Drawing
- Solar Panel Grounding
- Maps of Average Daily Solar Radiation Annually
- Maps of Average Daily Solar Radiation per Month

Navigation Tools

- Crosswalk Document Section Icons: Section icons provided along the right side of each page of the Crosswalk Document allow the user to navigate to a particular standard design topic.

  Internal Grounding — Inactive Page Icon – Click on icon to navigate to the Crosswalk Document topic

  Internal Grounding — Active Page Icon – Shows the current Crosswalk Document topic the user is reviewing

- Bullet Icons are provided throughout the Crosswalk Document:
  - Clicking on ADOBE icons allows the user to open the associated files in Adobe Reader.
  - Clicking on WORD icons allows the user to open the associated files in MS Word.
  - Hovering your mouse over NOTES icons provides addition information on the topic discussed.
  - Clicking on the CAMERA Icon will open photos associated with the topic.
  - Clicking on the BLM LOGO opens the RI CASHE web-based discussion relevant to the topic.
  - Clicking on the DOLLAR ICON will open up pricing estimates for the standard configuration type.

- Underlined Text provides links to external web sites, Motorola R56 pages or to documents contained on the Crosswalk Document Disc.

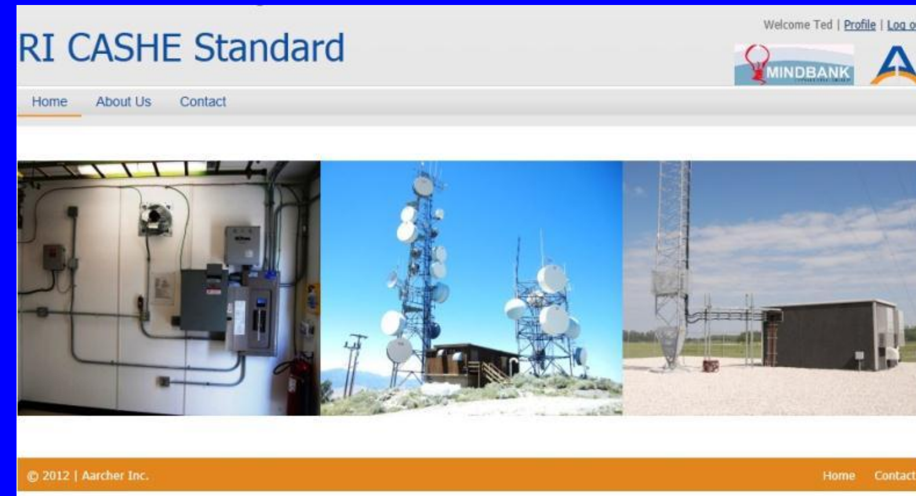
- Images: Hovering your mouse over images provides additional information. Clicking on images opens a full size file.

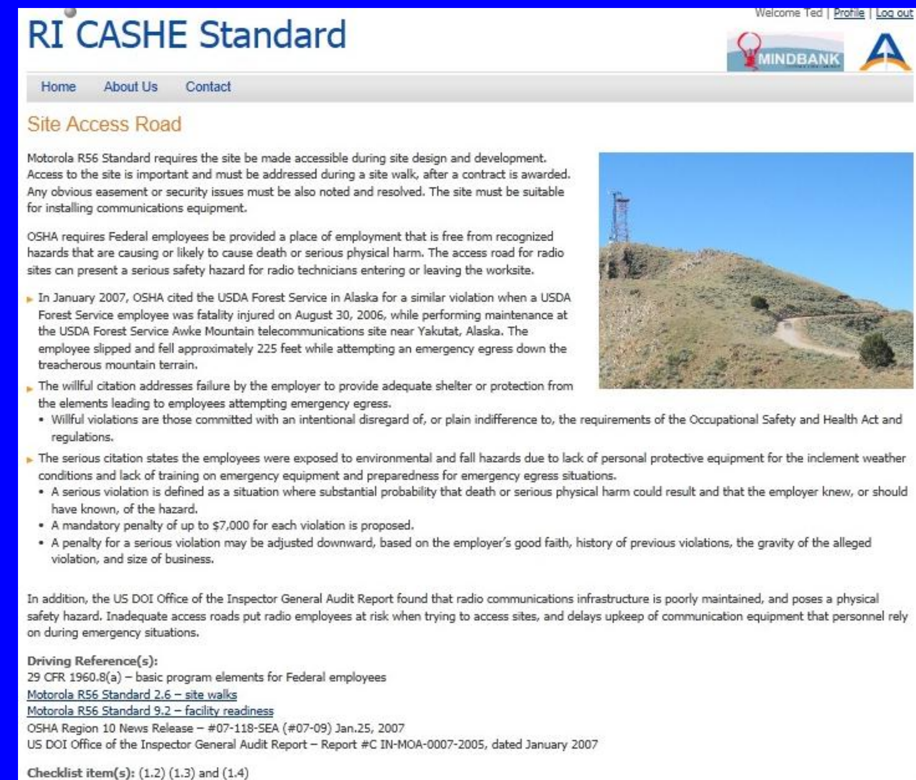
Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

RI CASHE Web-Based Discussions

- The RI CASHE Standard website is a resource for land mobile radio (LMR) facility managers responsible for understanding and implementing corrective action requirements identified through site assessment and audit programs. This is not intended as a comprehensive reference site, but rather a repository of individual explanatory pages referenced from assessment/audit findings. If a report link is not functional or you have other questions regarding the function or operation of this site, please see the Contact section of this site.
- Contents of the RI CASHE Standard website is accessed directly through links contained throughout this document. Clicking on the BLM icon links the user to a web-based forum where discussions regarding regulatory compliance, BLM-specific requirements, and links to the Motorola R56 citations are provided.
- The topics are customized to provide the reader with additional information and resources to aid in design of a new radio facility or effect corrective actions on existing facilities.
- Each web-based topic has the relevant driving references governing the proper installation or requirement. Each web-based topic will have links to the specific Motorola R56 citation.
- Some topics provide links to vendor web sites that identify materials needed to add in the bill of materials.
- To register for a login user name and password, click on the link below.

Self-Register for RI CASHE Standards





RI CASHE Standard

Welcome Ted | Profile | Log out

Home About Us Contact

Site Access Road

Motorola R56 Standard requires the site be made accessible during site design and development. Access to the site is important and must be addressed during a site walk, after a contract is awarded. Any obvious easement or security issues must be also noted and resolved. The site must be suitable for installing communications equipment.

OSHA requires Federal employees be provided a place of employment that is free from recognized hazards that are causing or likely to cause death or serious physical harm. The access road for radio sites can present a serious safety hazard for radio technicians entering or leaving the worksite.

- In January 2007, OSHA cited the USDA Forest Service in Alaska for a similar violation when a USDA Forest Service employee was fatality injured on August 30, 2006, while performing maintenance at the USDA Forest Service Awke Mountain telecommunications site near Yakutat, Alaska. The employee slipped and fell approximately 225 feet while attempting an emergency egress down the treacherous mountain terrain.
- The willful citation addresses failure by the employer to provide adequate shelter or protection from the elements leading to employees attempting emergency egress.
  - Willful violations are those committed with an intentional disregard of, or plain indifference to, the requirements of the Occupational Safety and Health Act and regulations.
- The serious citation states the employees were exposed to environmental and fall hazards due to lack of personal protective equipment for the inclement weather conditions and lack of training on emergency equipment and preparedness for emergency egress situations.
  - A serious violation is defined as a situation where substantial probability that death or serious physical harm could result and that the employer knew, or should have known, of the hazard.
  - A mandatory penalty of up to $7,000 for each violation is proposed.
  - A penalty for a serious violation may be adjusted downward, based on the employer's good faith, history of previous violations, the gravity of the alleged violation, and size of business.

In addition, the US DOI Office of the Inspector General Audit Report found that radio communications infrastructure is poorly maintained, and poses a physical safety hazard. Inadequate access roads put radio employees at risk when trying to access sites, and delays upkeep of communication equipment that personnel rely on during emergency situations.

Driving Reference(s):
29 CFR 1960.8(a) – basic program elements for Federal employees
Motorola R56 Standard 2.6 – site walks
Motorola R56 Standard 9.2 – facility readiness
OSHA Region 10 News Release – #07-118-SEA (#07-09) Jan.25, 2007
US DOI Office of the Inspector General Audit Report – Report #C IN-MOA-0007-2005, dated January 2007

Checklist item(s): (1.2) (1.3) and (1.4)

Key Personnel

BLM RI CASHE PROGRAM

- Compliance Assessment-Safety, Health, and the Environment
- Primary Contacts:
  - Ken Morin – BLM CASHE Program Lead kmorin@blm.gov
  - Jason Becker – BLM National Radio Operations Branch jbecker@blm.gov

Mindbank Consulting Group, LLC – *Subcontracted to Aarcher providing specialized knowledge of radio facilities*

- *Experience with tower audit programs for government agencies*
- *Experience with design and construction of wireless radio facilities*
- Primary Contact:
  - Ted Sumners – RI CASHE Project Manager tsumners@mindbank.com

Aarcher, Inc. – *Prime contractor for the BLM CASHE Program*

- Environmental consultants and regulatory compliance experts
- Manages BLM CASHE and RI CASHE Programs
- Primary Contact:
  - Bonnie Wisniewski – Aarcher CASHE Program Manager bwisniewski@aarcherinc.com

Aero Solutions, LLC – Subcontracted to Mindbank providing professional engineering services for tower designs

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Purpose of the Standard Radio Facility Design

The standard designs provide templates for use by engineers, radio technicians, and management that provide the following:

- Specifications documents
  - Provides interpretations of industry design standards specifically for land mobile radio facilities
  - Specifies installation materials to be used
  - Specifies installation methods and requirements
  - Provides cross references to Motorola R 56 sections, DOI checklist questions, and regulatory standards
- Typical design drawings
  - Provides a graphical representation of specifications for each typical radio facility type
  - Provides a standard template in AutoCAD format for use during radio facility development and planning
- Estimated budgetary pricing:
  - Provides detailed pricing for materials and labor for each typical radio facility type
  - Provides a budgetary tool for future planning
- Crosswalk document
  - Provides detailed descriptions, photographs, drawings and guidance on where, how and why devices are installed
  - Provides links to specifications documents, design drawings, pricing, and other resources
  - Provides links to feature-rich web discussions regarding regulatory and industry design standards

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Radio Facility Design Scope of Work

Develop plans and specifications for a standard radio facility that is fully compliant with the requirements in the Department of the Interior's Office of the Chief of Information Office (OCIO) Directive 2009-008, signed on December 9, 2009.

- The OCIO directive references numerous industry and regulatory standards the bureaus are to follow when designing, constructing, or operating a radio facility. Those standards include, but are not limited to, the following:
  - Occupational Safety and Health Administration (OSHA)
  - Motorola R56 Committee
  - Electronic Industries Alliance/Telecommunications Industry Association (EIA/TIA)
  - American National Standards Institute (ANSI)
  - National Fire Prevention Association (NFPA)
- A lengthy list of specific standards is provided in the OCIO Directive. The standard radio facility design is not limited to using only the standards identified in the OCIO Directive. New applicable or more recent standards are to be used, as well.
- The BLM RI CASHE Program has deviated from some Motorola R56 requirements. Those deviations are to be reflected in the standard design.
- The design effort does not include installation of radio frequency (RF) cabling or radio equipment. However, the standard design includes installation of infrastructure in the shelter, on the tower and between the shelter and tower to support installation of RF cabling, antennas, and radio equipment.

Radio Facility Design Standards

- Department of the Interior OCIO Directive 2009-008
- Motorola Reference Manual 56 (Motorola R56)
  - Standards and Guidelines for Communications Sites (09/01/05).
  - DOI received authorization from Motorola to utilize excerpts of the Motorola copyrighted Motorola R56 manual.
- Occupational Safety and Health Act (OSHA)
- National Fire Protection Agency (NFPA)
  - NFPA 70: National Electrical Code (NEC)
  - NFPA 780: Standard for the Installation of Lightning Protection Systems
- Federal Communications Commission (FCC)
  - FCC OET Bulletin No. 56
    - Questions and Answers about Biological Effects and Potential Hazards of Radio Frequency Electromagnetic Fields
  - FCC OET Bulletin No. 65
    - Evaluating Compliance With FCC Guidelines for Human Exposure to Radio Frequency Electromagnetic Fields
- American National Standards Institute (ANSI)
- Telecommunications Industry Association (TIA)

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Typical Radio Facility Designs

Plans and specifications developed and discussed in the Crosswalk Document provide for the construction of one of the following radio communication facility types:

- Traditional radio facility using a prefabricated radio equipment shelter with a communications tower
  - Designs include options for facilities to be powered by commercial power with battery backup or photovoltaic power with battery storage
  - Designs include options for variable shelter sizes and types as well as two options for a self-supporting tower or monopole tower with variable tower heights
- Radio facility with a prefabricated aluminum radio equipment shelter equipped with an attached articulating antenna mast
  - Designs include options for facilities to be powered by commercial power with battery backup or photovoltaic power with battery storage
  - The designs include options for variable shelter sizes and antenna mast heights
- Radio facility using a prefabricated outdoor radio equipment cabinet with antennas mounted on a pipe-mast powered by photovoltaic power with battery backup
- Radio facility using a prefabricated fiberglass shelter with antennas mounted inside the shelter and powered by photovoltaic power with battery backup
  - This is the typical shelter used in the Alaska interior
- Prefabricated radio equipment shelter only using commercial power with battery backup
  - This deliverable is intended to provide the field with a specification it may use to purchase just the shelter
- Prefabricated radio equipment shelter only using photovoltaic power with battery backup power
  - This deliverable is intended to provide the field with a specification it may use to purchase just the shelter

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Third-party Testing and Inspection Requirements

Section 01 45 23 – Third Party Testing and Inspecting Services

General contractors awarded the construction of new radio facilities or remediation of existing radio facilities must provide a pool of qualified independent firms to perform review, inspection, and testing services during the construction life cycle.

- The government will select the third-party inspector from a pool of at least three qualified inspectors from three different firms proposed by the Contractor.
- Third-party inspector is an individual or company, hired by, but not associated with, the company contracted to construct the radio site, nor associated with the government. The third-party inspector must possess demonstrated knowledge of LMR site construction and meet the following qualifications:
  - The third-party inspector must be radio expert, having a minimum of 15 years of experience with the design, installation, maintenance, and repair of remote mountain-top LMR radio systems, repeaters, remote controls, multiplexers, antenna systems, microwave systems, battery backup systems, and solar power systems;
  - The inspector will possess demonstrable experience and extensive knowledge with radio site construction operations and maintenance, RF emissions safety, and relevant industry standards and guidelines;
  - The inspector must have working knowledge of environmental/safety issues typically found at LMR facilities including, but not limited to, SARA Title III, propane storage, and diesel fuel storage issues associated with emergency power systems (e.g. batteries and generators); and
  - The Third Party Inspector must be a member of an inspection team with whom the inspector can consult on complex issues. The team shall include a qualified radio technician/engineer, and an electrical engineer who specializes in design of grounding systems at remote mountain-top locations.
- Third-party inspectors will provide the following activities:
  - Review design drawings prior to construction and advise the general contractor and government regarding design compliance with the standards;
  - Review of photos of belowgrade or encased site components provided by the general contractor; and
  - Physical onsite inspection of the radio facility at the completion of construction prior to the government's final acceptance. This includes completion of the DOI Radio Communication Site Inspection Checklist and testing the grounding system.

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Standard Radio Facility Design Contacts

Ken Morin, P.E.
Bureau of Land Management
CASHE Program Lead
303-236-6418
kmorin@blm.gov

Ted Sumners
Mindbank Consulting Group, LLC
RI CASHE Project Manager
303-563-4908
tsumners@mindbank.com

Facility Component – Cross Reference Table

TOPIC	SPECIFICATION	MOTOROLA R56 REFERENCE	CHECKLIST REFERENCE
Communications Tower	Section 33 81 13	2.12 – Tower Design and Construction	(2.7, 2.8, 2.9)
Tower Ground Ring	Section 33 79 16	4.7.6 – Tower Grounding	(4.7)
Tower Ground Bus Bar	Section 33 79 86	4.4.3.1 – Tower Ground Bus Bar	(4.9)
Prefabricated Communications Shelter	Section 13 34 18	3.3 – Building/Shelter Design and Location Considerations	(3.6, 3.7)
Shelter Ground Ring	Section 33 79 15	4.4.1.6 – External Building and Tower Ground Ring	(4.5)
Aluminum Shelter with Articulating Antenna Mast	Section 13 34 18.13	3.3 – Building/Shelter Design and Location Considerations	(3.6, 3.7)
Shelter Ground Ring	Section 33 79 15.23	4.4.1.6 – External Building and Tower Ground Ring	(4.5)
Outdoor Cabinet with Embedded 20-foot Antenna Mast	Section 13 34 18.13	3.3 – Building/Shelter Design and Location Considerations	(3.6, 3.7)
Outdoor Equipment Cabinet Grounding	Section 33 79 15.23	4.7.8 – Outdoor Cabinet Grounding	(4.5)
Aluminum Cabinet with Articulating Antenna Mast	Section 13 34 18.13	3.3 – Building/Shelter Design and Location Considerations	(3.6, 3.7)
Outdoor Equipment Cabinet Grounding	Section 33 79 15.23	4.7.8 – Outdoor Cabinet Grounding	(4.5)
Fiberglass Shelter with Antenna Radome	Section 13 34 18.23	3.3 – Building/Shelter Design and Location Considerations	(3.6, 3.7)
Shelter Ground Ring	Section 33 79 15	4.4.1.6 – External Building and Tower Ground Ring	(4.5)

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

External Grounding – Cross Reference Table

TOPIC	SPECIFICATION	MOTOROLA R56 REFERENCE	CHECKLIST REFERENCE
Ancillary Device Grounding	Section 33 79 20	4.7.10 – Metallic Objects Requiring Grounding	(4.2)
Grounding Electrodes	Section 33 79 83.13	4.4.1 – Grounding (Earthing) Electrodes	(4.3)
Supplemental Grounding Electrodes	Section 33 79 83.20	4.4.1 – Grounding (Earthing) Electrodes	(4.3)
Electrolytic Ground Rods	Section 33 79 83.33	4.4.1.3 – Electrolytic Ground Rods	(4.3)
External Grounding Conductors	Section 33 79 83	4.7.10 – Metallic Objects Requiring Grounding	(4.4)
Shelter Ground Ring	Section 33 79 15	4.4.1,6 – External Building and Tower Ground Ring	(4.5)
External Ground Bus Bar	Section 33 79 86	4.4.3 – External Ground Bus Bars	(4.6)
Tower Ground Ring	Section 33 79 16	4.4.1,6 – External Building and Tower Ground Ring	(4.7)
Tower Grounding	Section 33 79 16	4.7.6 – Tower Grounding	(4.8)
Tower Ground Bus Bar	Section 33 79 86	4.4.3.1 – Tower Ground Bus Bar	(4.9)
Grounding Electrode System Resistance	Section 33 79 83.53	4.7.4 – Grounding Electrode System Resistance	(4.10)
Special Grounding Situations	Section 33 79 83.63	4.11 – Special Grounding Situations	(4.11, 4.12, 4.13)
Ice Bridge Grounding	Section 33 79 83.23	2.12.8.1 – Ice Bridge and Cable Support Requirements	(8.12, 8.13)

Internal Grounding – Cross Reference Table

TOPIC	SPECIFICATION	MOTOROLA R56 REFERENCE	CHECKLIST REFERENCE
➢ **Internal Grounding System**	**DIVISION 33**	5.3 – Grounding System Components and Installation Requirements	Section 5
Master Ground Bus Bar	Section 33 79 86	5.3.1 – Master Ground Bus	(5.1)
Sub System Ground Bus Bar	Section 33 79 86	5.3.2 – Sub System Ground Bus Bar	(5.1)
Rack Ground Bus Bar	Section 33 79 84.16	5.3.5 – Rack Ground Bus Bar	(8.3)
Internal Perimeter Ground Bus	Section 33 79 85	5.3.7 – Internal Perimeter Ground Bus Conductors	(5.2)
Bonding Equipment to the Internal Grounding System	Section 33 79 84.13	5.4 – Connection Methods for Internal Grounding (Earthing) System	(5.3)
Internal Shelter Grounding Conductors	Section 33 79 84	5.4.1 – General Bonding Requirements	(5.4)

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Electrical – Cross Reference Table

TOPIC	SPECIFICATION	MOTOROLA R56 REFERENCE	CHECKLIST REFERENCE
COMMERCIAL POWER	**DIVISION 26**	**CHAPTER 6**	**SECTION 6**
➢ Basic Electrical Materials and Methods	Section 26 05 00	6.2.7 – Conductors & 6.2.8 - Conduit	**SECTION 6**
➢ Low Voltage Electrical Service Entrance	Section 26 21 13	6.2.1 – Electrical Service	(6.3, 6.6)
➢ Electricity Metering	Section 26 21 13	6.2.1 – Electrical Service	(6.3, 6.6)
➢ Panel Boards	Section 26 24 16	6.2.5 – Power Panels	(6.7, 6.8, 6.9, 6.11)
➢ Electrical Materials	Section 26 05 00	6.2.1 – Electrical Service	(6.3, 6.6)
SOLAR POWER	**DIVISION 26**	**CHAPTER 6**	**SECTION 6**
Photovoltaic Collectors Systems	Section 26 31 00	6.6 – Alternate Power sources	6.10
BATTERY BACKUP POWER	**DIVISION 26**	**CHAPTER 6**	**SECTION 6**
Battery Systems	Section 26 33 00	6.7 – Battery Systems	(6.13, 6.14, 6.15)

Specifications Format

Specification documents included in the standard radio facility design have been completed in the Construction Specifications Institute's (CSI) MasterFormat®.

- MasterFormat®, a publication of CSI and Construction Specifications Canada (CSC), is a master list of numbers and titles classified by work results. It is primarily used to organize project manuals and detailed cost information, and to relate drawing notations to specifications.
- Construction projects use many different kinds of delivery methods, products, and installation methods, but in common is the need for effective teamwork by the many parties involved to ensure the correct and timely completion of work. The successful completion of projects requires effective communication amongst the people involved; and that, in turn, requires easy access to essential project information. Efficient information retrieval is only possible when a standard filing system is used by everyone. MasterFormat® provides such a standard filing and retrieval scheme that can be used throughout the construction industry.
- MasterFormat® is used to organize specifications and other project information for most commercial building design and construction projects in North America. It lists titles and section numbers for organizing data about construction requirements, products, and activities. By standardizing such information, MasterFormat® facilitates communication among architects, specifiers, contractors, and suppliers, and helps all parties meet radio facility owners' requirements, timelines, and budgets.
- The purpose of this format is to assist the user in locating specific types of information. Information contained in CSI's MasterFormat® is organized in a standardized outline form within 50 divisions. Each division contains a number of sections.
- Each section is divided into the following three parts:
    - General
    - Products
    - Execution

Specifications Outline – Divisions 1, 2, and 13

DIVISION 01 - GENERAL REQUIREMENTS

- Section 01 00 00 – General Requirements
  - Section 01 31 00 – Project Management and Coordination
  - Section 01 33 00 – Submittal Procedures
  - Section 01 42 00 – Reference Standards and Definitions
  - Section 01 50 00 – Temporary Facilities
  - Section 01 60 00 – Product Requirements
  - Section 01 70 00 – Execution Requirements
- Section 01 11 00 – Summary of Work
- Section 01 45 23 – Third-Party Testing and Inspection Services
- Section 01 74 19 – Construction Waste Management and Disposal
- Section 01 77 00 – Contract Closeout Requirements
- Section 01 78 23 – Operations and Maintenance Data
- Section 01 78 39 – As-built Documents
- Section 01 78 39.13 – Project Record Documents
- Section 01 81 13 – Sustainable Design Requirements

DIVISION 02 - EXISTING CONDITIONS

- Section 02 21 00 – Site Surveys

DIVISION 13 - SPECIAL CONSTRUCTION

- Section 13 34 18 – Prefabricated Communications Shelter
- Section 13 34 18.13 – Prefabricated Aluminum Shelter with Articulating Antenna Mast
- Section 13 34 18.23 – Prefabricated Fiberglass Communications Shelter with Antenna Radome
- Section 13 34 18.33 – Outdoor Equipment Cabinet
- Section 13 34 23 – Prefabricated Shelter Foundation

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Specifications Outline - Divisions 26, 27, 31 and 32

DIVISION 26 - ELECTRICAL

- Section 26 05 00 – Basic Electrical Materials and Methods
- Section 26 21 13 – Low-voltage Electrical Service Entrance
- Section 26 24 16 – Panel boards
- Section 26 27 13 – Electricity Metering
- Section 26 31 00 – Photovoltaic Collectors
- Section 26 33 00 – Battery Systems

DIVISION 27 - COMMUNICATIONS

- Section 27 05 10 – Cabling Requirements-Cable Trays-Ladders and Racks
- Section 27 11 16 – Equipment Racks
- Section 27 11 16.13 – Equipment Cabinet and Rack Installation
- Section 27 11 16.23 – Equipment Installation in Racks and Cabinets

DIVISION 31 - EARTHWORK

- Section 31 10 00 – Site Clearing
- Section 31 20 00 – Earthwork-Grading
- Section 31 23 16 – Excavation and Fill
- Section 31 23 17 – Trenching
- Section 31 23 23 – Utility Backfill Materials

DIVISION 32 - EXTERIOR IMPROVEMENTS

- Section 32 31 13 – Chain-Link Fences and Gates

Specifications Outline - Division 33

DIVISION 33 - UTILITIES

- Section 33 79 15 – Communications Shelter Grounding
- Section 33 79 15.13 – Outdoor Cabinet Grounding
- Section 33 79 15.23 – Aluminum Shelter with Telescoping Mast Grounding
- Section 33 79 16 – Tower Grounding
- Section 33 79 20 – Bonding Metallic Ancillary Devices to External Grounding System
- Section 33 79 83 – External Ancillary Device Grounding Conductors
- Section 33 79 83.13 – Grounding Electrodes
- Section 33 79 83.20 – Supplemental Grounding Electrodes
- Section 33 79 83.33 – Electrolytic Ground Rods
- Section 33 79 83.53 – Grounding Electrode System Resistance
- Section 33 79 83.63 – Special Grounding Situations
- Section 33 79 84 – Internal Shelter Grounding Conductors
- Section 33 79 84.13 – Bonding Equipment to Internal Grounding System
- Section 33 79 84.16 – Rack Ground Bus Bar
- Section 33 79 85 – Internal Perimeter Ground Bus
- Section 33 79 86 – Ground Bus Bars
- Section 33 81 13 – Communications Transmission Towers
- Section 33 82 33.23 – RF Cable Ice Bridge

Radio Facility Design Inclusions/Exclusions

A typical land mobile radio facility is comprised of the major components depicted in Figure 1.

INCLUDED IN STANDARD DESIGNS

INCLUDED

- Compound
  - Fenced compound (optional)
  - Parking area
- Communications equipment shelter (options)
  - Two standard prefabricated shelter sizes
  - Two lightweight shelters with articulating antenna mast sizes
  - Outdoor equipment cabinet
  - Shelter with enclosed antenna radome
- RF cable ice bridge between the shelter and tower
- Tower (options)
  - Two standard tower heights
  - Two standard antenna loading configurations
- Power system (options)
  - Commercial power (battery backup option)
  - Renewable energy (photovoltaic with batteries)
- External grounding system
  - Tower and shelter ground rings
  - Ancillary device grounding
- Internal grounding and bonding system
  - Master ground bus bar (single point grounding)
  - Internal perimeter ground (ancillary device bonding)

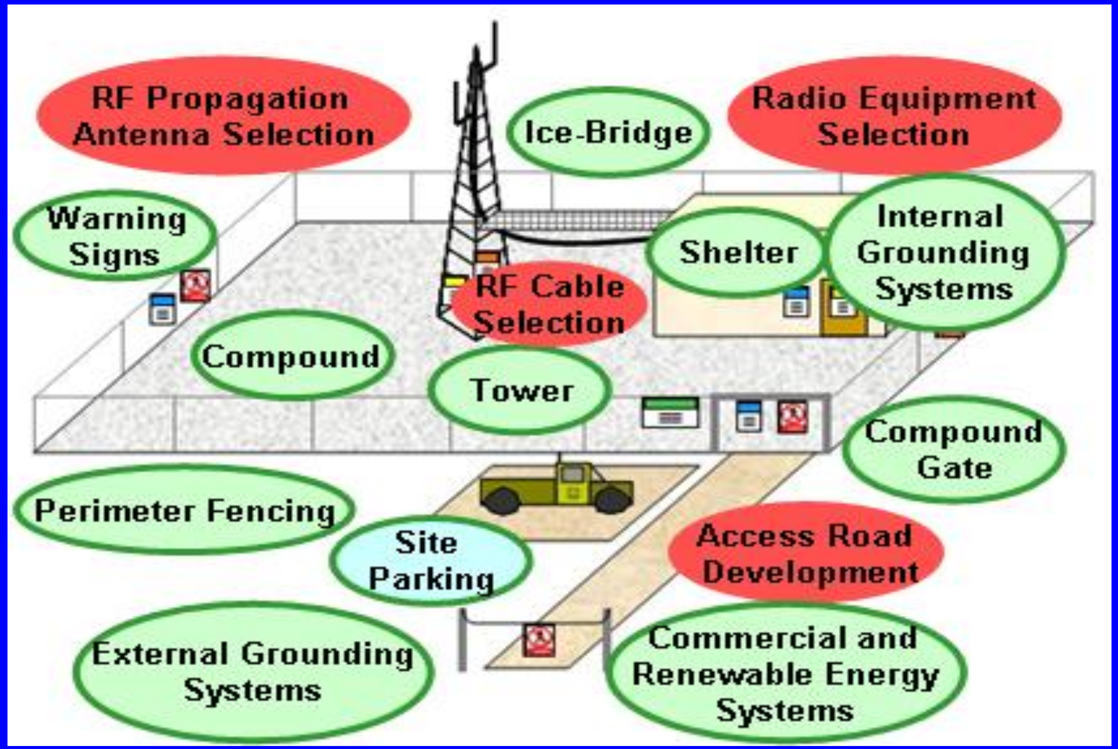


FIGURE 1

NOT INCLUDED IN STANDARD DESIGNS

NOT INCLUDED

- Access road development
- Radio equipment selection
- RF cabling selection
- RF propagation and design
- Antenna selection

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Design Drawings and Workbooks

Design drawing packages and specification workbooks have been assembled for each typical radio facility type. The drawing files are in Adobe PDF format and the specification workbooks are in MS Word format.

- Click on the ADOBE icon to view the drawing file.
- Click on the DOLLAR icon to view budgetary pricing.
- Click on the WORD icon to view the specification workbook.
  - The specification workbooks contain all specifications created for each facility type.
  - All site design variables are contained in the Summary of Work Section in each workbook.

8-foot wide, 12-foot long, Prefabricated Shelter with 40-foot to 60-foot tower

8-foot wide, 16-foot long, Prefabricated Shelter with 60-foot to 80-foot tower

Fiberglass Shelter with Antenna Radome

8-foot wide, 12-foot long, Lightweight Aluminum Shelter with Articulating Antenna Mast

8-foot wide, 16-foot long, Lightweight Aluminum Shelter with Articulating Antenna Mast

Lightweight Aluminum Cabinet with Articulating Antenna Mast

Outdoor Equipment Cabinet with Antenna Pipe Mast

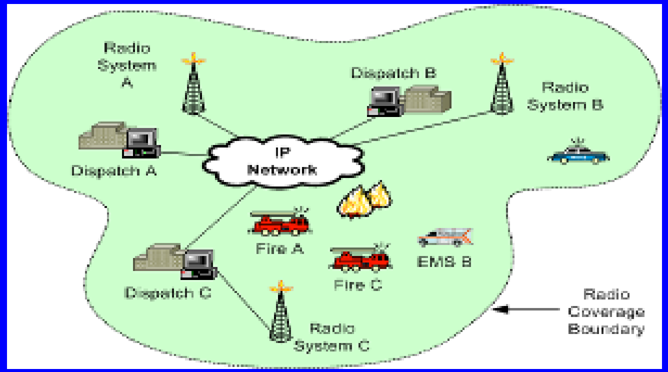
Tower Design Drawings

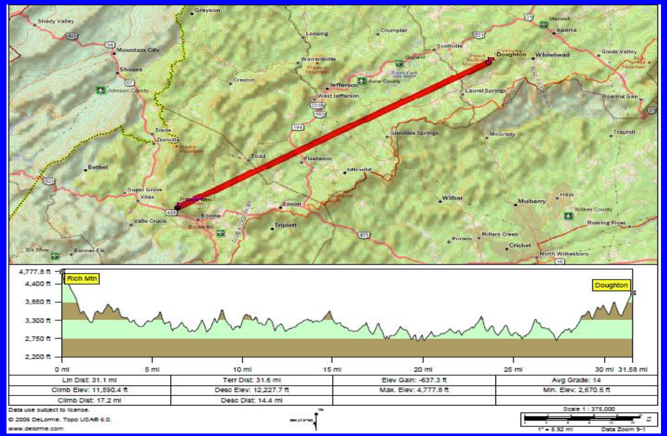
- Typical tower designs are not intended to be used for construction of a new radio facility
- The typical towers are designed with maximum antenna loading based on presumptive soils and not actual soil conditions

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Conceptual Design

- End-user communications requirements
  - Communications usage and capacity
  - Geography where communications is required
  - Interoperability requirements with other entities
  - Technology requirements to meet end user requirements
- Interconnectivity with other system components
  - Line of site microwave paths
  - Telephone data circuits
  - Radio over internet protocol (ROIP)
- Equipment design and selection
  - Communications equipment type and size requirements
  - Equipment rack space requirements
  - Equipment shelter size requirements
- RF design and coverage
  - Path analysis from each candidate for microwave backhaul
  - LMR signal propagations
  - Antenna selection
  - Tower height requirements
  - RF cable selection





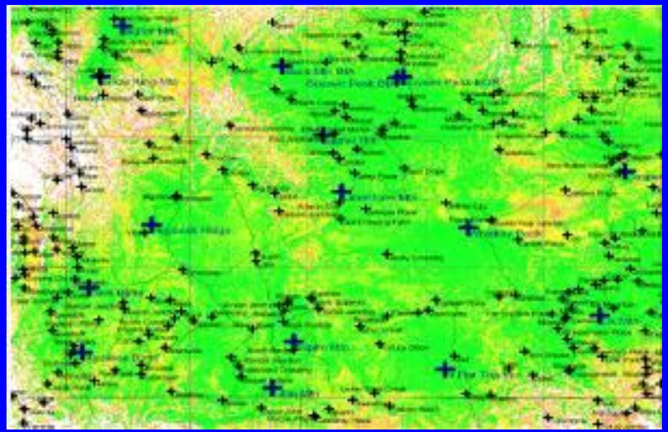


Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Radio Facility Candidate Search

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

FACILITY CANDIDATE SEARCH

- Radio facility candidates should meet RF coverage requirements for two-way communications and microwave backhaul pathways.
- Prior to construction of a new radio facility, search for the availability of existing radio facilities for collocation. Collocation agreements may include the following documentation:
  - Memorandum of Understanding (MOU)
  - Memorandum of Agreement (MOA)
  - Leasing, right-of-way, and easements
- The accessibility of proposed radio facility locations must be investigated to determine feasibility to transport shelters , towers, and associated foundations to the location. Improvements to the access route may be required to facilitate delivery of equipment and for continuous year round maintenance.
  - Helicopter-access only locations should be avoided whenever possible because of increased cost for construction and maintenance
- Available space and topography of the proposed radio facility location must be considered for placement of the shelter, tower, and other components.
- Availability and distance of existing commercial power and local private telephone utilities to the proposed radio facility location must be considered.
- Regulatory compliance and due diligence at the proposed radio facility location must include the following:
  - Radio frequency authorization (RFA)
  - Local jurisdiction permitting and zoning;
  - National Environmental Policy Act (NEPA)
  - State Historic Preservation Office (SHPO)
  - Tower Construction Notification System (TCNS)
  - Federal Aviation Administration (FAA)

Preliminary Civil Design

Preliminary Civil Design of a radio facility must include the following:

Site Layout Plan

- The site layout plan shows the proposed location of major site components including the shelter, tower, existing and proposed utility routes, photovoltaic array, generator, and fuel storage tanks;
- The tower must be designed a minimum of 10 feet from the shelter and ideally 30 feet to decrease the amount of lighting energy diverted into the shelter; and
- The shelter access door should be oriented to the south at locations where snow and ice may accumulate.

Civil Survey

- Civil surveys provide a legal description of the property and a detailed drawing (map) including the location of existing markers, boundaries, easements, encroachments, utilities, roads, and other terrain features.

Topographical Land Survey

- Mapping to indicate the elevations and contours of the land; and shows both natural and artificial features (e.g. streams buildings, quarries, fences, roads, woodlands, etc.).

Utility Locates and Staking

- Utility location is the process of identifying and labeling public utility mains located underground. These mains may include lines for telephones, electricity distribution, natural gas, cable television, fiber optics, traffic lights, street lights, storm drains, water mains, and wastewater pipes. In some locations, major oil and gas pipelines, national defense communication lines, mass transit, rail, and road tunnels also compete for space underground.

Geotechnical Survey (Motorola R56, Section 2.4.6 – Geotechnical Considerations)

- A geotechnical survey includes a detailed investigation of the soil to determine the soil strength, composition, water content, and other important soil characteristics.

Soil Resistivity Measurements (Motorola R56, Appendix B – Soil Resistivity Measurements)

- Soil resistivity directly affects the design of a grounding (earthing) electrode system. Prior to the design and installation of a new radio facility, the proposed location must be tested to determine the soil's resistivity.

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Preliminary Communications Equipment Shelter Design

The preliminary design for the communications equipment shelter must consider the following:

- The shelter must be sized to accommodate the planned and future radio equipment and support apparatus as well as collocation of cooperator equipment.
- Accessibility to the radio facility location must be considered when selecting the size, type, and weight of the shelter.
  - Helicopter access only facilities can increase shelter delivery costs.
  - Facilities with narrow or steep access routes can make delivery of large shelters prohibitive and increase delivery costs.
- Shelter structure, exterior walls, and roof must be designed and suited for the environment.
- Shelter floor loading design strength must accommodate the weight of the radio equipment racks and batteries.
- Availability of commercial power must be considered to provide proper electrical specifications to the shelter vendor.
  - Photovoltaic-powered facilities may not require the typical AC power panel, lighting, and electrical outlets.
- Heat generation by the equipment installed inside the shelter and average temperatures at the radio facility must be considered to provide information to the shelter vendor for designing heating ventilation and air conditioning (HVAC) equipment.
- When designing the initial layout of the facility, the shelter entrance door should be designed to face south whenever possible. Installing the access door to the south provides protection from prevailing winds from the north, minimizes snow drifts near the door, and provides adequate sun during the spring to melt away accumulated snow and ice.
  - Second option would be for the entrance door to face west.
  - Third option would be for the entrance door to face east.
  - Where the only option is to install the shelter door facing north, the facility design should provide the following protection measures:
    - Install a 7-foot tall chain-link fence, equipped with nonmetallic slats, located 6 to 8 feet to the north of the shelter. This will provide protection from northern wind exposure and provide protection from drifting snow; and
    - Install a 42-inch wide entry way cover (awning) over the shelter access door to provide protection to the access door and steps from falling snow.

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Preliminary Tower Design – Obstruction Evaluation

Preliminary design of a radio facility with a communications tower must evaluate the following:

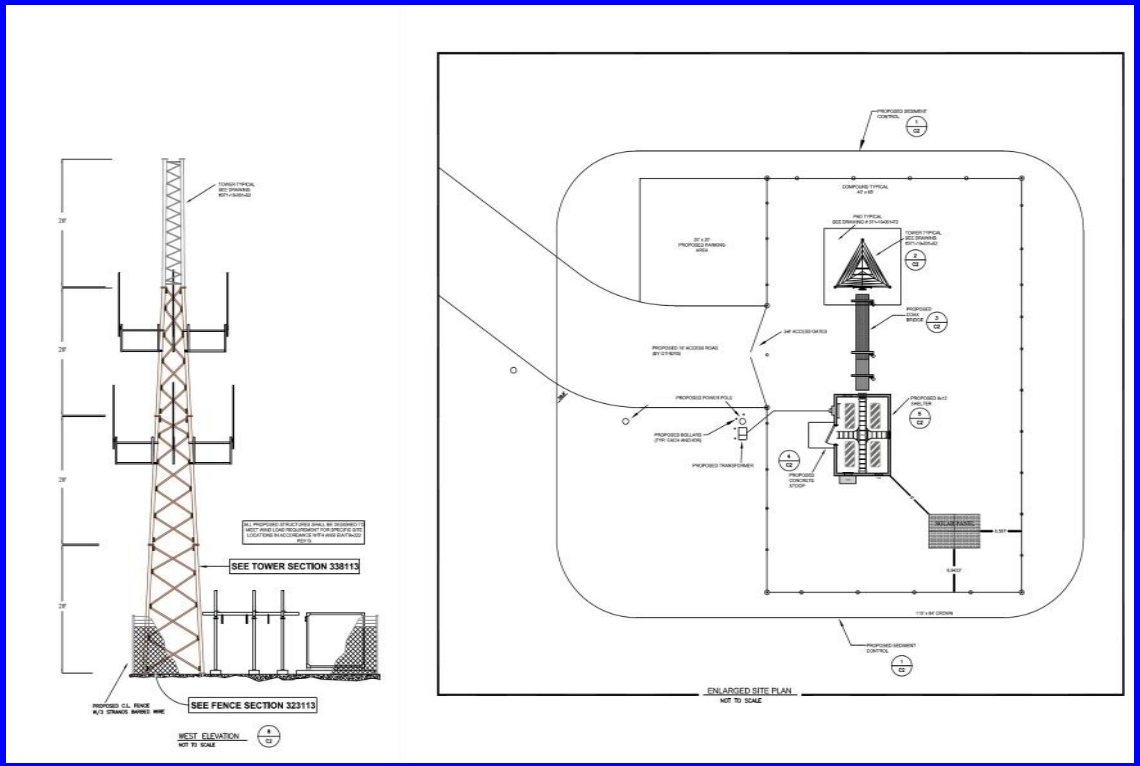
FAA Obstruction Evaluation (IAW - FAA Order 8260.19E, Appendix 3) and 14 CFR 77.

- The obstruction evaluation is required when the proposed tower height exceeds 200 feet in accordance with 14 CFR 77.9 (a)
- When the tower exceeds an imaginary surface extending outward and upward at any of the slopes detailed in 14 CFR 77.9 (b)
- Any highway, railroad, or other traverse way for mobile objects, of a height which, if adjusted upward 17 feet for an Interstate Highway that is part of the National System of Military and Interstate Highways where overcrossings are designed for a minimum of 17 feet vertical distance, 15 feet for any other public roadway, 10 feet or the height of the highest mobile object that would normally traverse the road, whichever is greater, for a private road, 23 feet for a railroad, and for a waterway or any other traverse way not previously mentioned, an amount equal to the height of the highest mobile object that would normally traverse it, would exceed a standard of paragraph (a) or (b) of this section in accordance with 14 CFR 77.9 (c)
- Any construction or alteration on any of the following airports and heliports:
  - A public use airport listed in the Airport/Facility Directory, Alaska Supplement, or Pacific Chart Supplement of the US. Government Flight Information Publications
  - A military airport under construction, or an airport under construction that will be available for public use
  - An airport operated by a Federal agency or the DOD
  - An airport or heliport with at least one FAA-approved instrument approach procedure
- Notice for construction or alteration does not need to be filed for the following:
  - Any object that will be shielded by existing structures of a permanent and substantial nature or by natural terrain or topographic features of equal or greater height, and will be located in the congested area of a city, town, or settlement where the shielded structure will not adversely affect safety in air navigation;
  - Any air navigation facility, airport visual approach or landing aid, aircraft arresting device, or meteorological device meeting FAA-approved siting criteria or an appropriate military service siting criteria on military airports, the location and height of which are fixed by its functional purpose;
  - Any construction or alteration for which notice is required by any other FAA regulation; or
  - Any antenna structure of 20 feet or less in height, except one that would increase the height of another antenna structure.

Final Design of a Radio Facility

Final design of a radio facility includes the following designs and drawings:

- Civil site improvement engineering and drawings
  - Site clearing
  - Earthwork grading
  - Excavation and fill
- Tower Designs
  - Antenna loading
  - RF cable loading
  - Structural steel
  - Tower foundation
  - Tower assembly
- Shelter Designs
  - Structural designs with added variable selections
  - Shelter foundation design
- Electrical Designs
  - Commercial Power
  - Grounding
  - Photovoltaic Power



Typical Site Layout Plan

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Shelter Design Variables

Section 13 34 18 – Prefabricated Communications Shelter

The specification document for the prefabricated equipment shelter has multiple design variables to customize the the radio facility shelter. Click the design variables image to view and complete a printable form. Shelter variable selections include the following:

- Dimensions
- Exterior finish and color
- Wind loading
- Roof snow loading
- Live floor loading
- Battery loading
- Seismic design considerations
- Electrical options for commercial and photovoltaic power distribution
- Air-conditioner size for commercial powered facilities
- Cross-ventilation systems are required on all shelters
  - Exhaust fan with intake vent
  - Venturi cross-ventilation system
  - Passive cross-ventilation system
- Cable ladder size
- RF cable entrance port size
- Options for equipment rack installation by the shelter vendor

Section 13 34 18 – Prefabricated Communications Shelter				Variable Paragraph
Specifier Note	SPECIFIER NOTE: Concrete Foundations are optional. Shelters are to be designed with metal skids capable of placement directly on substantially level soil. If a Concrete Foundation is not required, Omit SECTION 13 34 23 – Prefabricated Shelter Foundation			
Specifier Note	SPECIFIER (2.1.B.1): Choose shelter internal dimensions (ID). Delete inapplicable selection and associated image.			
(2.1.B.1)	Shelter Internal Width (ID):		Feet, Inches	Section 13 34 18 (2.1.B.1)
(2.1.B.1)	Shelter Internal Length (ID):		Feet, Inches	Section 13 34 18 (2.1.B.1)
(2.1.B.1)	Shelter Internal Height (ID):		Feet, Inches	Section 13 34 18 (2.1.B.1)
Specifier Note	SPECIFIER (2.1.C): Choose Exterior Shelter Finish Type in paragraph 2.1.C.			
(2.1.C)	Shelter Exterior Finish:	Stone aggregate fiberglass Aluminum Concrete		Section 13 34 18 (2.1.C)
Specifier Note	SPECIFIER (2.1.D): Choose Exterior Shelter Finish Color in paragraph 2.1.D.			
(2.1.D)	Shelter Exterior Color:			Section 13 34 18 (2.1.D)
Specifier Note	SPECIFIER (2.1.E): Choose Interior Shelter Finish in paragraph 2.1.E.			
(2.1.E)	Shelter Interior Finish:			Section 13 34 18 (2.1.E)
Specifier Note	SPECIFIER (2.1.F.1): Specify Shelter design Wind Loads in paragraph 2.1.F.1. SPECIFIER (2.1.F.2): Specify Shelter design Roof Snow Load in paragraph 2.1.F.2. SPECIFIER (2.1.F.3): Specify Shelter design Live Floor Load in paragraph 2.1.F.3. SPECIFIER (2.1.F.3.a): Provide additional floor loading criteria for batteries including Manufacturer, Model, Battery Weight and Battery Base Dimensions. SPECIFIER (2.1.F.4): Specify Shelter Seismic design zone. SPECIFIER (2.1.F.5): Specify Shelter design Exposure Category.			
(2.1.F.1)	Shelter Wind Load:		MPH	Section 13 34 18 (2.1.F.1)
(2.1.F.2)	Shelter Roof Snow Load:		PSF	Section 13 34 18 (2.1.F.2)
(2.1.F.3)	Shelter Live Floor Load:		PSF	Section 13 34 18 (2.1.F.3)
(2.1.F.3.a.1)	Battery Manufacturer:		MFR Name	Section 13 34 18 (2.1.F.3.a.1)
(2.1.F.3.a.2)	Battery Model Number:		MFR Part Number	Section 13 34 18 (2.1.F.3.a.2)
(2.1.F.3.a.3)	Battery Weight:		LBS	Section 13 34 18 (2.1.F.3.a.3)
(2.1.F.3.a.4)	Battery Base Width:		Inches	Section 13 34 18 (2.1.F.3.a.4)
(2.1.F.3.a.5)	Battery Base Length:		Inches	Section 13 34 18 (2.1.F.3.a.5)
(2.1.F.4)	Shelter Seismic Design Zone (Max Ground Acceleration)	0.5 inch 0.625 inch	Zone 0 = (0.04g) Zone 1 = (0.08g) Zone 2A = (0.16g) Zone 2B = (0.20g) Zone 3 = (0.33g) Zone 4 = (0.5g)	Section 13 34 18 (2.1.F.4)
(2.1.F.5)	Shelter Exposure Category			Section 13 34 18 (2.1.F.5)
Specifier Note	SPECIFIER: (2.6) Commercial Electrical Equipment is Optional. May not be included on Renewable Energy Powered sites. Delete section or modify to suit actual site conditions.			
Specifier Note	SPECIFIER: (2.6.C) The following shall be supplied by the shelter manufacturer where compliance with the local utility power company requirements and local codes are known at the time the shelter order is placed.			
Specifier Note	SPECIFIER: (2.6.C.1) Specify Electrical Service-Disconnect and Meter configuration and supplied service-current ratings or modify to suit the actual electrical service requirements of the site. Choose to provide a combination meter socket with main service-disconnect panel (OR) a separate meter panel and service-disconnect panel.			
(2.6.C.1)	Service-Disconnect Current Rating:		Amperes	Section 13 34 18 (2.6.C.1)
(2.6.C.1)	Main Circuit Breaker Rating:		Amperes	Section 13 34 18 (2.6.C.1)
Specifier Note	SPECIFIER: (2.6.C.D) Choose Electrical Panel Board service-current ratings or modify to suit the actual electrical service requirements of the site.			
(2.6.D)	Primary Panel Board Current Rating:		Amperes	Section 13 34 18 (2.6.D)
(2.6.D)	Main Circuit Breaker Rating:		Amperes	Section 13 34 18 (2.6.D)

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Typical Shelter – Selection Considerations

Motorola R56, Section 3.3 – Building/Shelter Design and Location

- Consideration to the amount and type of equipment to be housed, along with adequate space for movement and expansion within the shelter.
  - Radio equipment configuration typically dictates the shelter design.
- The desired size and composition of a prefabricated shelter must be considered along with weight in transporting the shelter to the facility.
- All facilities utilizing a prefabricated structure with manned access must utilize exterior lighting to some extent, as provided in Motorola R56, Section 3.11.4 - Exterior Lighting.
  - Exception: If the radio facilities are located in the Alaskan interior or are only accessed during daylight hours.
- A single point grounding system is required.
  - This includes an external ground connection point located at each RF, electrical power, tower light controller, and telecommunications cabling entrance to the shelter.
  - Each grounding connection is to be bonded to a shelter ground ring serving as the single point grounding system.
- Though not usually required for building foundations, some facilities with unique soil conditions may require soil boring tests.
  - Soil borings reveal the soil strength and water content, which are used to design a suitable foundation.
- Foundation design and equipment anchoring must address seismic requirements in earthquake-prone areas with a moment magnitude rating or 3 or greater.
- Shelter foundations (when used) must be equipped with a concrete-encased electrodes (Ufer ground).
  - The Ufer must be bonded to the shelter ground ring and electrical service grounding system.
- All shelters must be designed or use features that prevent entry of animals and insects into the structure. Design should discourage bird and small animal nesting on exterior features of the structure.
- Shelters must be of the type designed to house electronic equipment and fitted with locking doors.

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Typical Shelter Devices

Section 13 34 18 – Prefabricated Communications Shelter

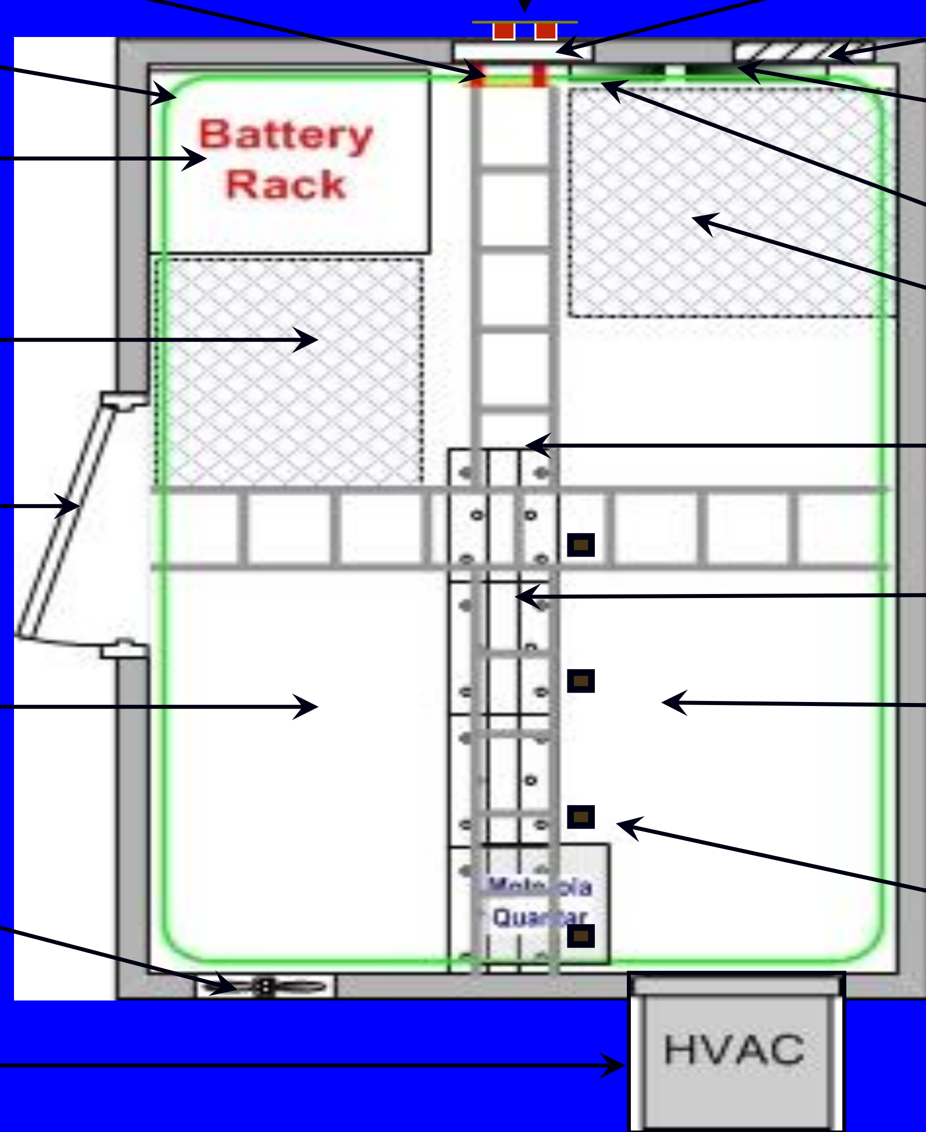


Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Typical Shelter – Delivery Considerations

Motorola R56, Section 3.3 – Building/Shelter Design and Location

- Prefabricated shelters and cabinets may have fully or partially installed equipment prior to shipment to the radio facility.
  - Shelter manufacturers may have to modify the shelter design to allow lifting with equipment installed
  - Weight and size of the shelter must be considered if the radio facility location has limited access
- State building certification may be required if prefabricated shelters are manufactured in a different State than the one in which deployed.
- Shipping a prefabricated shelter to a radio facility location may require special road-use permits and/or special transportation methods (crane, double-length truck, helicopter, etc.).
- Narrow access roads or rough road conditions may prohibit access to large tractor trailers or cranes required to deliver and offload the shelter.
  - Smaller delivery vehicles or universal boom trucks with flatbeds may be required to negotiate access roads to remote radio facility locations.
- Helicopter delivery costs are relative to the weight of the shelter and the altitude of the radio facility location.
  - Heavier shelters will require a larger aircraft with greater lifting capacity;
  - Higher altitudes limit the lifting capacity of the aircraft; and
  - Lightweight fiberglass or aluminum shelter options are included in the standard designs.
- For shipping on public roadways, shelters must meet strict dimensional requirements, including accounting for protrusions such as HVAC, RF entry assemblies, or electrical service entrances.
  - Some devices may need to be installed after delivery to the radio facility location.

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Typical Shelter – Design Options

Section 13 34 18 – Prefabricated Communications Shelter

Three Shelter Exterior Types are considered

- Stone Aggregate/Concrete
- Aluminum
- Fiberglass

Shelter Size Assumptions

- Minimum one equipment rack or cabinet (8 feet wide, 6 feet long, 9 feet high)
- Minimum three equipment racks or cabinets (8 feet wide, 12 feet long, 9 feet high)
- Minimum five equipment racks or cabinets (8 feet wide, 16 feet long, 9 feet high)
  - Equipment rack dimensions (19 inches wide, 84 inches high, EIA standard)
  - Equipment cabinet dimensions (24 inches wide, 24 inches deep, 84 inches high)

Reserved Equipment Space for Growth and Reserved Space for Battery Systems

- 30-inch minimum workspace in front and behind radio equipment
- 36-inch minimum clearance and workspace in front of electrical equipment
- 36-inch minimum clearance for ingress/egress

Internal Grounding

- Master ground bus bar (MGB) installed within 24 inches below the RF cable entrance
- Internal perimeter ground bus (IPGB) or Halo ground ring for bonding of all metallic ancillary devices
- Noncurrent carrying, metallic ancillary devices must be bonded to the IPGB or MGB
- Each equipment rack or cabinet will be equipped with a rack ground bus bar (RGB) bonded to the MGB. Equipment racks must not be bonded to the IPGB

Power Options

- Commercial power with options for 100-Ampere and 200-Ampere service equipment
- Options for photovoltaic-power and battery backup systems

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Typical Shelter – Lighting

Section 13 34 18 – Prefabricated Communications Shelter

Motorola R56, Section 3.11 – Lighting

The shelter must be equipped with an interior lighting system consisting of quality grade 80-watt surface-mounted fluorescent light fixtures equipped with Lexan-type diffusers, and RF interference noise suppression filters.

- The system must be designed to provide a minimum illumination of 70 foot candles at 36 inches above the floor in front of and behind equipment rows.
  - Fixtures to be two-lamp, 48-inch x 18-inch wrap-around type
  - Provide a timer switch installed near the entry door to control the lights
  - Provide a minimum of two light fixtures in front and behind equipment rows
- Light fixtures must be equipped with protective covers

The Motorola R56 Standard requires an exterior light be installed near the door of the equipment shelter to provide lighting for personnel entering and exiting the shelters. Exterior lighting requirements are concerned with lighting for points of entry and exit from the building and for perimeter security.

- ➢ The light fixture must be National Electrical Manufacturers Association (NEMA) Type 3, weather-resistant, and suitable for outdoor use.
- OSHA requires exit routes within the workplace are adequately lighted so an employee with normal vision can see along the exit route. According to NFPA, the floors within an exit must be illuminated with at least 1 foot-candle (10.8 lux) measured at the floor.
- ➢ Lighting on remote facilities can be seen for miles at night and in some cases, may cause objections from neighbors. To address these issues, on-demand systems such as infrared-proximity sensors and twist-knob timers are recommended.
- Light-emitting diode (LED) lights, installed in conjunction with a timer switch, will allow for adequate lighting in the shelter while keeping power consumption to a minimum.

Lights In Front and Behind Equipment Racks

Exterior Light Near Access Door

Typical Light Timer Switch

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Typical Shelter – Air Conditioner Design

Motorola R56 Standard 3.8.1 – HVAC design considerations

The Motorola R56 Standard requires ambient temperatures inside the shelter to be maintained in a range within the specified requirements for each piece of equipment. Equipment manuals may specify either operating or ambient temperature. Operating temperature refers to the temperature in the equipment case, while the equipment is operating at a given capacity or load. Ambient temperature refers to the environmental temperature as measured 5 feet above the floor in the center of the equipment aisle.

- Air-conditioners are not required on photovoltaic-powered facilities. Photovoltaic-powered facilities require ventilation systems and heaters (where required) to maintain battery-operating temperatures.
- In lieu of manufacturer environmental standards, the HVAC system must be capable of maintaining interior conditions at 64º to 75º F and reducing humidity to 30% to 55% relative humidity.
- Self-contained, wall-mounted HVAC units are acceptable in most applications; however, the system must meet the following requirements:
  - Be within the appropriate BTU limit for the shelter;
  - Be commercial-grade. Consumer-grade household units or window-mounted units are not permitted;
  - To reduce operating costs and prevent the compressors from freezing during cold weather, all units must be equipped with heating elements and an economizer that allows the shelter to be cooled by external air if the outdoor temperature falls below a predetermined value;
  - HVAC systems using external air circulation features may not be suitable for environments having unusually high dust or particulate emissions;
  - Have a backup HVAC unit installed and available unless a single unit is designed with an alarm or remote terminal;
  - If a redundant HVAC system is installed, it must be designed in a lead-lag configuration to cycle with the primary unit in order to subject all units to equal wear;
  - If two HVAC units are required to provide sufficient cooling, one additional unit must suffice for redundancy; and
  - Account for local fire codes that may require an automatic shutdown circuit for HVAC units should the smoke/heat alarm activate.

Commercial Grade Air Conditioner Units

Consumer Grade Air Conditioner Units are not Permitted

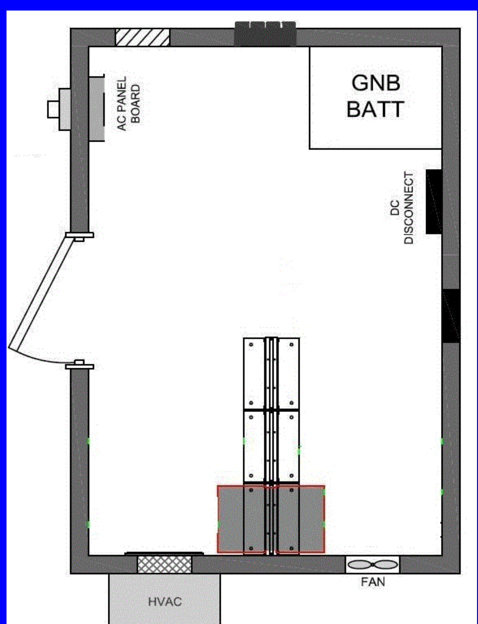
Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Typical 8-foot wide x 12-foot long Prefabricated Shelter

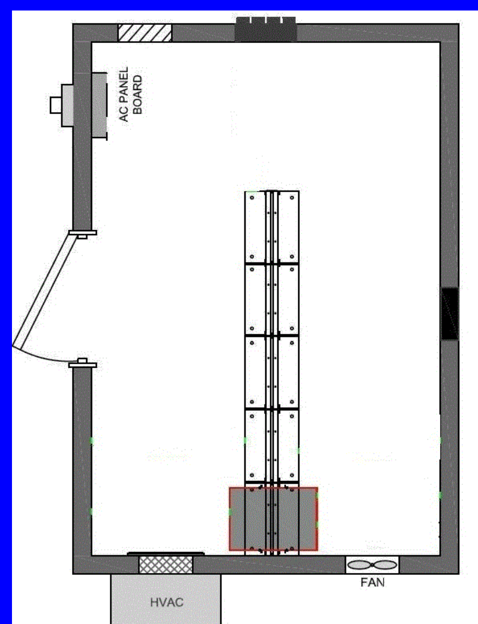
Designed 8-foot wide x 12-foot long shelter layout drawings

- Commercial power with battery backup (accommodates three equipment racks).
- Solar power with standard battery backup (accommodates three to four equipment racks).
- Solar power with extended battery backup (accommodates three equipment racks).
- Commercial power without battery backup (accommodates five equipment racks).
  - *Batteries may be stacked or mounted in an equipment rack to free up additional floor space*
  - *Standard battery backup includes one string of two to eight , 104 Ampere/hour batteries*
  - *Extended battery backup includes two strings of two to eight , 104 Ampere/hour batteries*

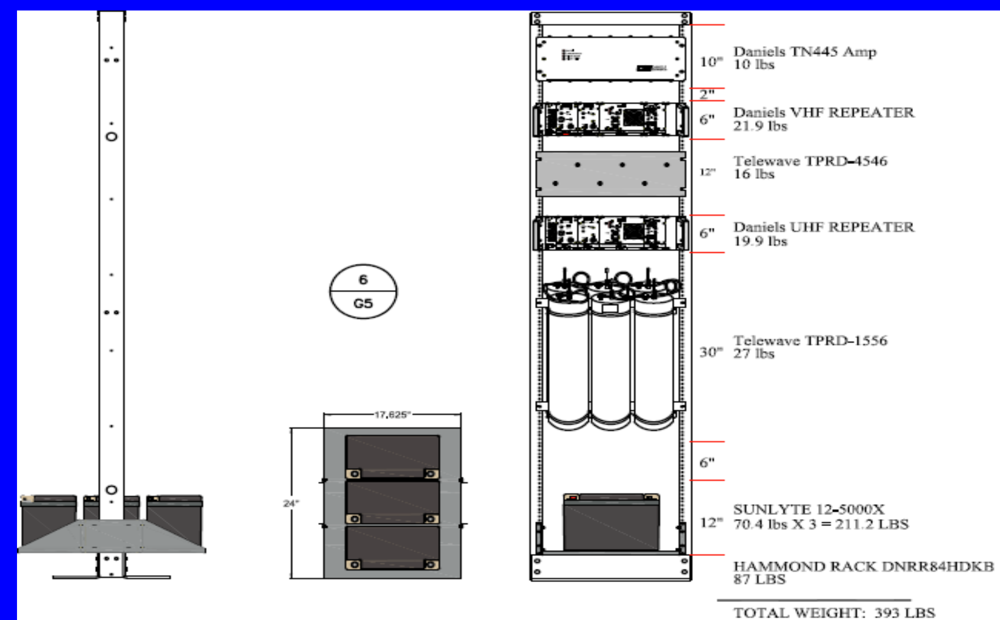
Alternative shelter size and equipment layout drawings are available



Commercial Power with Battery Backup



Commercial Power without Battery Backup



84-inch high, 19-inch wide Equipment Rack with Batteries

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Typical Drawing Files – 8-foot wide x 12-foot long Prefabricated Shelter with Tower

- 8x12_Prefabricated Shelter with 40-foot to 60-foot Tower Typical Drawing Package
- Individual drawing sheets
  - DWG A1_8x12_Typical Shelter Configurations
  - DWG A2_8x12_Shelter Foundation Details Example
  - DWG A3_8x12_Shelter Elevation Details
  - DWG C1_8x12_Civil Survey Example
  - DWG C2_8x12_Site Layout Plan
  - DWG E1_8x12_Electrical Site Plans
  - DWG E2_8x12_Shelter Panel Board Schedule
  - DWG E3_8x12_External Grounding Plan
  - DWG E4_8x12_Interior Grounding Plan
  - DWG E5_ 8x12_Battery Typicals
  - DWG E6_8x12_Photovoltaic One-Line Typical
  - DWG E7_8x12_ Electrical Notes
  - DWG F1_Tower Foundation Notes Placeholder
  - DWG F2_Tower Foundation Drawings Placeholder
  - DWG G1_8x12_Grounding Typical Drawings
  - DWG G2_8x12_Construction Typical Drawings
  - DWG G3_8x12_Monopole Typical Drawings
  - DWG G4_8x12_Construction Typical Drawings
  - DWG G5_8x12_Equipment Rack Installation
  - DWG G6_Construction Typical Drawings - Alternate Shelter Layout
  - DWG S1_Tower Steel Notes Placeholder
  - DWG S2_Tower Steel Drawings Placeholder

PDF FILES:
Click on the file to open file in Adobe

DWG DWG Files
AutoCAD Program Required

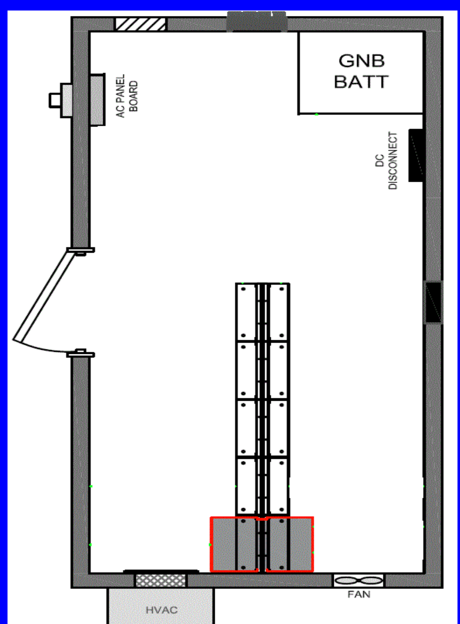
Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Typical 8-foot wide x 16-foot long Prefabricated Shelter

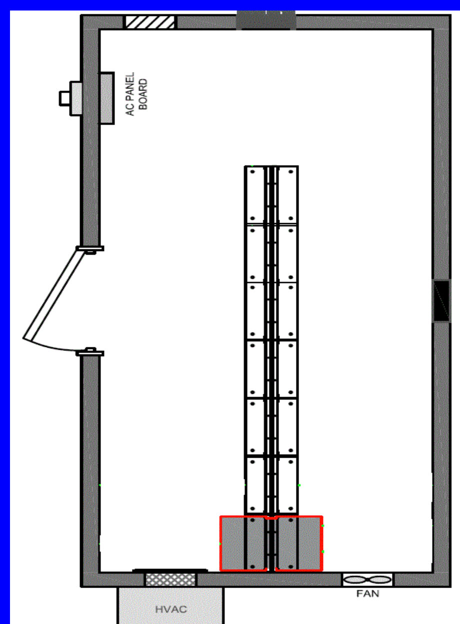
Designed 8-foot wide x 16-foot long shelter layout drawings

- Commercial power with battery backup (accommodates five equipment racks).
- Solar power with standard battery backup (accommodates five equipment racks).
- Solar power with extended battery backup (accommodates five equipment racks).
- Commercial power without battery backup (accommodates seven equipment racks).
  - ❖ *Batteries may be stacked or mounted in an equipment rack to free up additional floor space*
  - ❖ *Standard battery backup includes one string of two to eight , 104 Ampere/hour batteries*
  - ❖ *Extended battery backup includes two strings of two to eight , 104 Ampere/hour batteries*

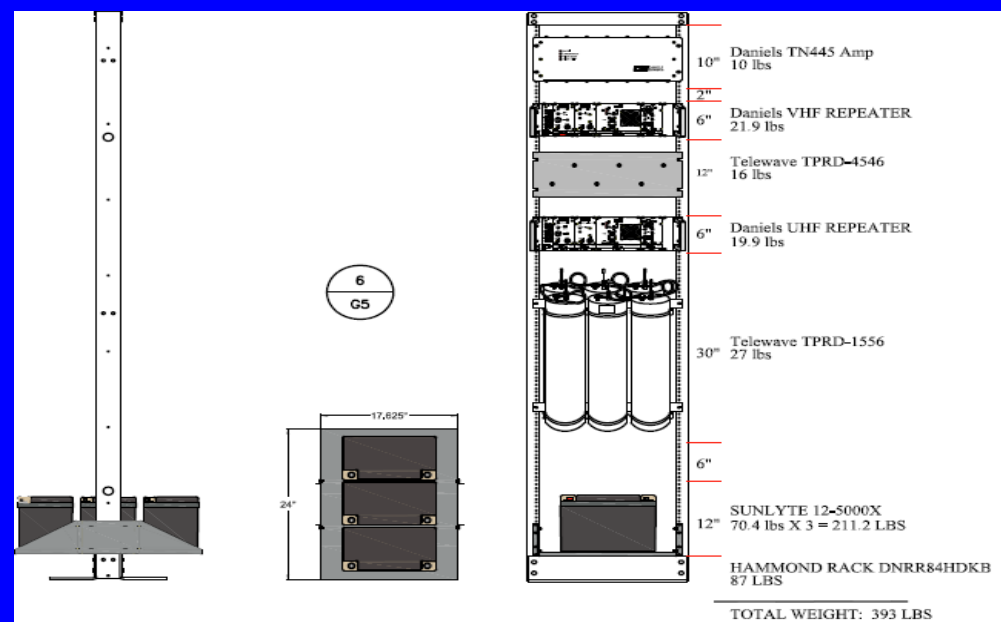
Alternative shelter size and equipment layout drawings are available.



Commercial Power with Battery Backup



Commercial Power without Battery Backup



84-inch high, 19-inch wide Equipment Rack

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Typical Drawing Files – 8-foot wide x 16-foot long Prefabricated Shelter with Tower

- 8x16_Prefabricated Shelter with 60 to 80-foot Tower Typical Drawing Package
- Individual drawing sheets
  - DWG A1_8x16_Typical Shelter Configurations
  - DWG A2_8x16_Shelter Foundation Details Example
  - DWG A3_8x16_Shelter Elevation Details
  - DWG C1_8x16_Civil Survey Example
  - DWG C2_8x16_Site Layout Plan
  - DWG E1_8x16_Electrical Site Plans
  - DWG E2_8x16_Shelter Panel Board Schedule
  - DWG E3_8x16_External Grounding Plan
  - DWG E4_8x16_Interior Grounding Plan
  - DWG E5_8x16_Battery Typicals
  - DWG E6_8x16_Photovoltaic One-Line Typical
  - DWG E7_8x16_ Electrical Notes
  - DWG F1_Tower Foundation Notes Placeholder
  - DWG F2_Tower Foundation Drawings Placeholder
  - DWG G1_8x16_Grounding Typical Drawings
  - DWG G2_8x16_Construction Typical Drawings
  - DWG G3_8x16_Monopole Typical Drawings
  - DWG G4_8x16_Construction Typical Drawings
  - DWG G5_8x16_Equipment Rack Installation
  - DWG G6_Alternate Shelter Layout Drawings
  - DWG S1_Tower Steel Notes Placeholder
  - DWG S2_Tower Steel Drawings Placeholder

PDF FILES:
Click on the file to open file in Adobe

DWG DWG Files
AutoCAD Program Required

Minimum Tower Design Requirements

Section 33 81 13 – Communications Transmission Towers

Tower steel and foundations must be designed to accommodate future growth and to allow for collocation of cooperators.

- To accommodate growth, each tower must be designed to allow for future addition of at least one 20-foot tower section.
- All towers must be designed to meet the latest version of ANSI/TIA-222 – Structural Standard for Antenna Supporting Structures and Antennas, (Currently Revision G-1, 2007).
- To optimize and standardize antenna mounting locations on the tower, the following design criteria should be met:
  - Three-leg tower designs must position one tower leg to an azimuth of 0 degrees magnetic or true north.
  - Four-leg tower designs must position one tower face to an azimuth of 0 degrees magnetic or true north.
- All tower foundation designs must be based on actual soil conditions determined by a geotechnical survey performed at the proposed tower location.
- All tower designs must be performed by a registered professional engineer with a license in the jurisdiction regulating the geographical location where the tower is to be installed.
- Towers must be manufactured by a firm (vendor) with the demonstrated experience and capability to perform the manufacturing.
- Antenna loading on towers must be designed to maximize available installation space on the tower and to maximize the antenna loading design for future growth.
  - A minimum of three antenna mounting locations (on 3-foot to 6-foot standoff brackets) should be designed for each mounting height; and
  - Antenna mounting heights should be designed with 20 feet of vertical spacing to minimize RF interference and to accommodate the length of omnidirectional antennas.
- To manage the amount of RF energy at ground level, the following antenna installation criteria must be met:
  - Omnidirectional antenna mounts must not be installed lower than 30 feet above ground; and
  - Microwave antenna mounts must not be installed lower than 25 feet above ground.
- Towers must be equipped with climbing access facilities equipped with climber safety apparatus. Safety apparatus and anchorage points must meet the minimum 5,000 pound anchorage requirements
- All towers must be equipped with either perimeter fencing or an anticlimb apparatus.

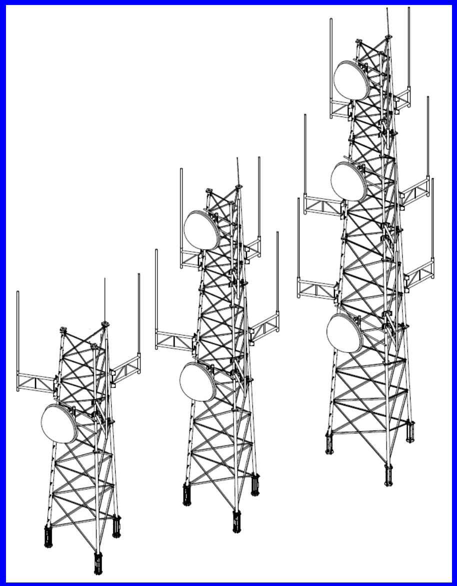
Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Example Tower Designs

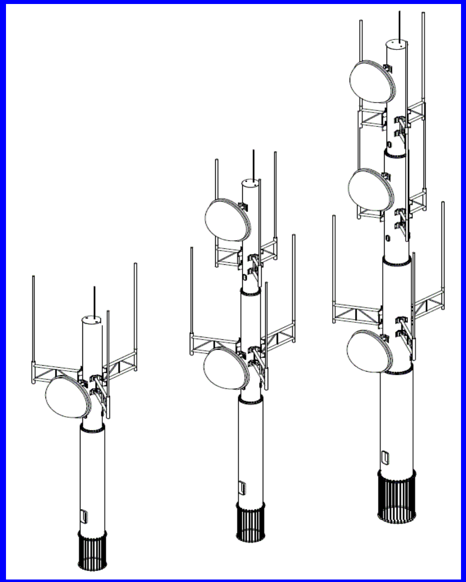
The example towers provided in the standard radio facility design are engineered to allow for future addition of a 20-foot tower section.

- Two typical tower steel fabrication types
  - Self-supporting lattice (based on the Rohn SSV)
  - Monopole (based on Rohn flanged monopole)

- Two typical tower design heights for each fabrication type
  - 40-foot designed for growth to 60 feet
    - Designed with three omnidirectional antenna mounts at 30 feet and one microwave dish at 25 feet
    - Designed for growth to 60 feet with three additional omnidirectional antenna mounts at 47 feet and an additional microwave dish at 55 feet
  - 60-foot designed for growth to 80 feet
    - Designed with three omnidirectional antenna mounts at 30 feet and three omnidirectional antenna mounts at 47 feet
    - Designed with two microwave dish mounts at 25 feet and 50 feet
    - Designed for growth to 80 feet with three additional omnidirectional antenna mounts at 67 feet and an additional microwave dish at 75 feet



Self-Supporting Lattice



Monopole

Tower Design Standards

Section 33 81 13 – Communications Transmission Towers

in accordance with ANSI/TIA-222-G-1-2007

Design Considerations Using The ANSI/TIA-222-Rev G Standard

The Rev G TIA Standard contains new parameters that significantly affect the magnitude of wind, ice, and earthquake loading. In addition to specifying the location of a structure for determining the basic wind speed, design ice thickness, and earthquake accelerations, it is important to consider these parameters when designing proposed structures and when modifying existing structures.

- **Classification of Structures (reliability)** (ANSI/TIA-222-G, Section 2.2 and Table 2.1)
  Classification of structures allows for the adjustment of wind, ice, and earthquake loading to match the reliability requirements for a specific application. Three reliability classes have been established based on the type of service provided and on the structure's potential hazard to human life and property. Wind, ice, and earthquake loading requirements progressively increase from Class I to Class III structures.

- **Exposure Categories (terrain)** (ANSI/TIA-222-G, Section 2.6.5)
  Exposure categories are used to adjust wind loading based on the type of terrain surrounding a site. Reduced wind loads are associated with rougher terrains that tend to slow the wind down. Three exposure categories have been defined based on terrain roughness. Wind loading is increased as the exposure designation changes from Exposure B (roughest terrain) to Exposure D (smoothest terrain).

- **Topographic Categories (elevated facilities)** (ANSI/TIA-222-G, Section 2.6.6)
  Topographic categories are used to determine increases in wind loading for facilities located on hills and other elevated locations (other than buildings). The shape and size (topography) of an elevated site determines the increase in wind load. Although many elevated facilities have their own unique features, the intent is to idealize these facilities into one of the standard topographic categories described in the following paragraph. For structures supported on buildings, it is only necessary to specify the height of the building and the surrounding exposure category.

The height of an elevated site above the surrounding terrain must be specified in order to determine the full extent of wind loading in accordance with ANSI/TIA-222-G. This should not be confused with the elevation of the site. Elevations of the site and the surrounding terrain may be used to determine height.

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Tower Design Classification

ANSI/TIA-222-G-1-2007 (Section 2.2 and Table 2.1)

Class I: Structures used for services where a delay in returning the service would be acceptable and the structure represents a low hazard to human life and/or property. Example services include residential wireless and conventional 2-way radio communications; television, radio, and scanner reception; wireless cable; and amateur and CB radio communications. Structures of this classification are exempt from ice and earthquake loading and wind loads are reduced 13% compared to Class II structures.

Class II: Structures used for services that may be provided by other means or structures that represent a significant hazard to human life and/or property. Example services include commercial wireless communications; television and radio broadcasting; cellular; PCS; CATV; and microwave communications.

Class III: Structures specifically designed for essential communications or structures that represent a substantial hazard to human life and/or property. Examples of essential communications would be: civil or national defense; emergency, rescue, or disaster operations; and military and navigation facilities. Loadings are increased for structures of this classification compared to Class II structures (15% for wind, 25% for ice, and 50% for earthquake).

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Tower Design Exposure Categories

ANSI/TIA-222-G-1-2007 (Section 2.6.5)

Exposure B: Urban, suburban, or wooden areas. The wind load at ground level is reduced by 18% compared to Exposure C. This reduction diminishes with height, making the overall wind reduction less significant for taller structures. In order to qualify for the wind load reduction, the rough terrain must extend in all directions from the site at least twenty times the height of the structure but not less than 0.5 mile [0.8 km].

Exposure C: Flat, open country and grasslands. Shorelines in hurricane-prone areas are currently included in this exposure due to the roughness of waves generated during hurricanes; however, research is continuing regarding wind loading for hurricane areas.

Exposure D: Flat, unobstructed areas exposed to wind flowing over open water or smooth terrain for at least 1.0 mile [1.6 km]. Examples would be shorelines of large bodies of water and areas adjacent to or within mud or salt flats. The wind load at ground level is increased 21% compared to Exposure C. The higher wind load applies to structures located within 20.0 times their height from an Exposure D terrain. An exception is permitted for facilities located in an Exposure B terrain that are at least 2.0 miles [3.2 km] from the Exposure D terrain. Under these conditions, the site may be classified as Exposure C.

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Tower Design Topographic Categories

ANSI/TIA-222-G-1-2007 (Section 2.6.6)

Category 1: Flat or rolling terrain with no abrupt changes in general topography. No increase in wind loading is required for this category.

Category 2: Facilities separated from a lower elevation by a gently sloping terrain (escarpment). Wind loads at the crest are 2.0 times the wind loads for a flat site and diminish with height depending on the height of the escarpment. Height for an escarpment is the difference in elevation between the upper and lower levels. Increased wind loads do not apply for structures located in the lower half of the sloping terrain or located beyond 8.0 times the escarpment's height from the crest.

Category 3: Facilities located at the top or within the upper half of a hill. Wind loads at the top of a hill are 2.3 times the wind loads for a flat site and diminish with height depending on the height of the hill. Height for facilities on isolated hills is the difference in elevation between the top and bottom of the hill. For facilities on prominent hills surrounded by other hills, height is the difference in the hill elevation at the site and the average elevation of the surrounding hills within a 2-mile radius (3.2-Km). In other words, height is the projection of the hill exposed to wind. When there are hills surrounding the site, increased wind loads do not apply unless the height of the hill at the site is at least 3.0 times the average height of the surrounding hills.

Category 4: Facilities located on a ridge. Wind loads at the top of a ridge are 3.0 times the wind loads for a flat site and diminish with height depending on the height of the ridge. Height for a ridge is the difference between the top and bottom elevations of the ridge.

Category 5: This category is reserved for facilities where site-specific investigations are performed to determine wind loading.

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Typical Tower Design Assumptions and Considerations

Section 33 81 13 – Communications Transmission Towers
in accordance with ANSI/TIA-222-G-1-2007 (Section 2.0)

The standard designs include options for a self-supporting lattice tower and a flanged monopole at variable heights between 40 and 80 feet. The designs use the following design categories and classifications as defined in ANSI/TIA-222-G:

- Tower Design Structure Classification – Class III
  Structures specifically designed for essential communications or structures that represent a substantial hazard to human life and/or property. Examples of essential communications include civil or national defense; emergency, rescue, or disaster operations; and military and navigation facilities. Loadings are increased for structures of this classification compared to Class II structures (15% for wind, 25% for ice, and 50% for earthquake).

- Tower Design Exposure Category – Exposure C:
  Flat, open country and grasslands. Shorelines in hurricane prone areas are currently included in this exposure due to the roughness of waves generated during hurricanes; however, research is continuing regarding wind loading for hurricane areas.

- Topographic Categories – Category 3
  Facilities located at the top or within the upper half of a hill. Wind loads at the top of a hill are 2.3 times the wind loads for a flat site and diminish with height depending on the height of the hill. Height for facilities on isolated hills is the difference in elevation between the top and bottom of the hill. For facilities on prominent hills surrounded by other hills, height is the difference in the hill elevation at the site and the average elevation of the surrounding hills within a 2-mile radius (3.2-Km). In other words, height is the projection of the hill exposed to wind. When there are hills surrounding the site, increased wind loads do not apply unless the height of the hill at the site is at least 3.0 times the average height of the surrounding hills.

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Typical Tower Design Loading Criteria

Section 33 81 13 – Communications Transmission Towers
in accordance with ANSI/TIA-222-G-1-2007

Typical tower designs use the following tower loading criteria:

- **Wind and ice:** (ANSI/TIA-222-G, Section 2.6)
  - A basic wind speed without ice = 120 Mph, 3-second gust wind speed
  - A design ice thickness = 1-inch with a density of 56 PCF for radial ice considered with wind
  - A basic wind speed with ice = 60 Mph, 3-second gust wind speed
  - A design rime ice thickness = 10-inch with a density of 30 PCF for rime ice considered without wind
  - The 1-inch radial ice thickness was based on the ASCE 7-1995 Commentary that has a map of the lower 48 States indicating a 50-year reoccurrence interval. A greater ice thickness would only affect a few areas of the county
- **Allowable soil bearing pressure** = 2,000 PSF Unit weight of soil = 110 PCF Frost depth = 60 inches
- **Earthquake:** (ANSI/TIA-222-G, Section 2.7)
  - Equivalent lateral force procedure (method 1) used for seismic analysis
  - Seismic site Class C for rock foundations
  - Seismic site Class D for soil foundation
  - Ss = 1.25
  - S1 = 0.5

Five foundation types considered:

- Mat (self-supporting tower and monopole tower)
- Drilled pier (self-supporting tower)
- Embedded foundation (monopole tower)
- Pad and pier Foundation (monopole tower)
- Rock foundation (self-supporting tower)

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Tower Foundation Design Requirements

Motorola R56 Section 2.12.1 - Tower Design Drawings

Tower foundation drawings must show the following information at a minimum:

- Reference to the soil/geotechnical report, including file number, date, and firm performing report, used in calculations and design
- Required concrete compressive strength to be achieved at 28 days
- Grade and/or type of reinforcing bar
- Concrete coverage requirements
- Whether welding rebar is permitted
- Whether cold joints are permitted; if so, the joining procedure must be specified
- Whether permanent steel casings are permitted for caisson installations
- Whether temporary steel casings are or may be required due to the expected soil conditions
- Any recommended concrete installation techniques
- References to all codes (and sections of codes) applicable for the design
- Plan, elevation, and section views depicting a minimum of the following:
  - Length, depth, and width diameter
  - Finish grade with respect to top of foundation
  - Rebar size and placement
  - Anchor bolt size, type, and placement
  - Above finish grade requirement for anchor heads (typically a minimum of 12 inches)
  - Estimated cubic yards of concrete per pier, caisson, mat, block or other type of foundation
  - Backfill requirements such as, but not limited to the following:
    - Material type
    - Lift thickness (typically lifts not more than 12 inches thick are acceptable)
    - Applicable compaction requirements; such as 95% of modified proctor maximum dry density
    - Applicable sub-grade compaction requirements; such as for a guy anchor (upon completion of the excavation the designer may require certain compaction densities)
  - Any other pertinent information that may be abstracted from the soils report, such as a high water table or large boulders

Typical Self-Supporting Tower – Antenna Loading Assumptions

Tower Designs Provided by
Aero Solutions, LLC

The following antennas and mounting heights are used in the typical design for self-supporting towers (SST):

- **40-foot SST designed for growth to 60 feet**
  Designed antenna loading parameters
  - One 2-meter microwave dish mounted 25 feet above grade level (AGL)
  - Three DB224-C omnidirectional antenna mounted 30 feet AGL

- **60-foot SST designed for growth to 80 feet**
  Designed antenna loading parameters
  - One 2-meter microwave dish mounted 25 feet AGL
  - Three DB224-C omnidirectional antenna mounted 30 feet AGL
  - Three DB224-C omnidirectional antenna mounted 47 feet AGL
  - One 2-meter microwave dish mounted 55 feet AGL

- **80-foot SST**
  Designed antenna loading parameters
  - One 2-meter microwave dish mounted 25 feet AGL
  - Three DB224-C omnidirectional antenna mounted 30 feet AGL
  - Three DB224-C omnidirectional antenna mounted 47 feet AGL
  - One 2-meter microwave dish mounted 55 feet AGL
  - Three DB224-C omnidirectional antenna mounted 67 feet AGL
  - One 2-meter microwave dish mounted 75 feet AGL

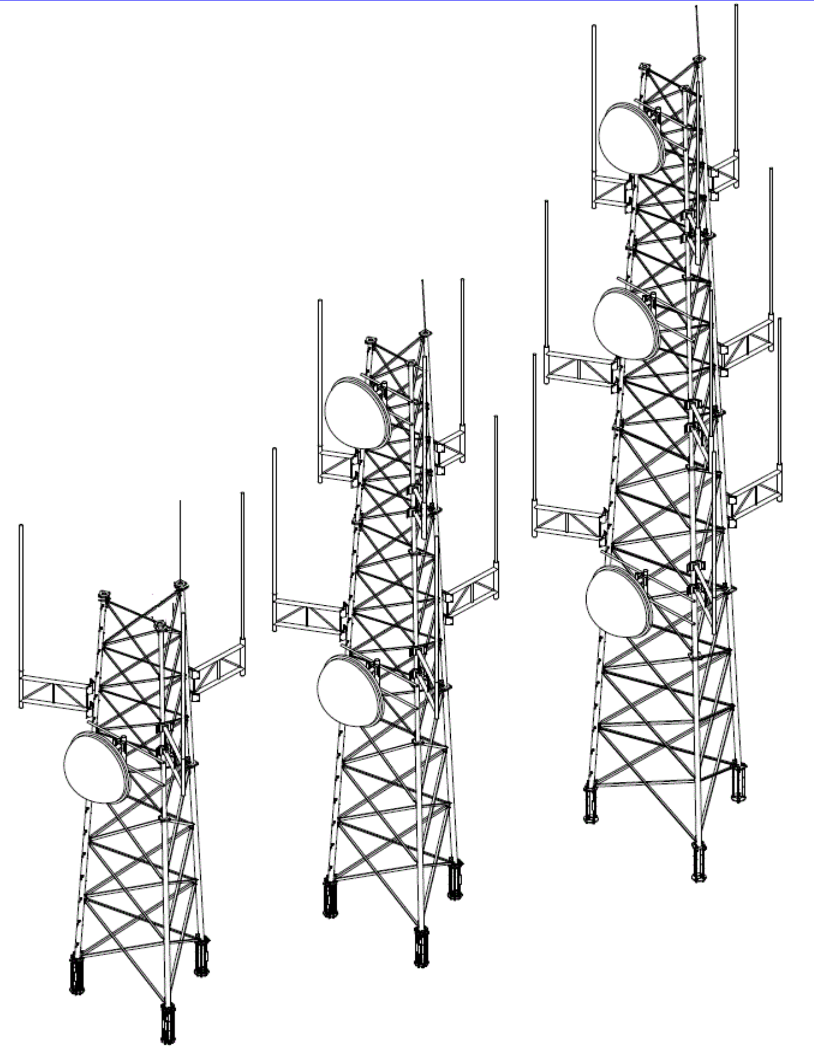
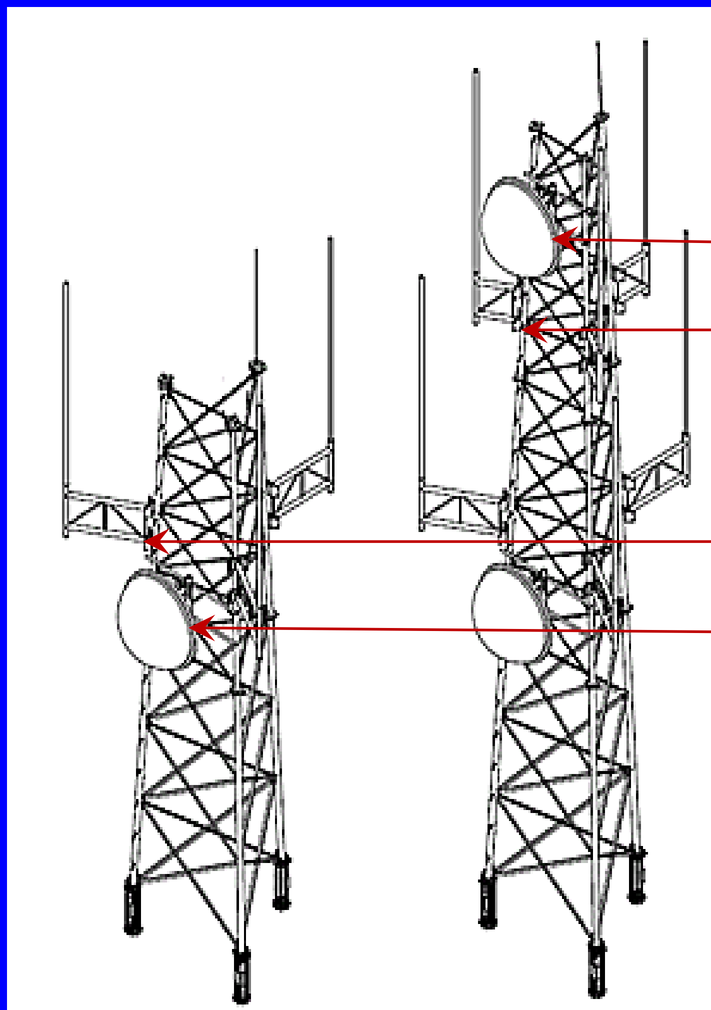


Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

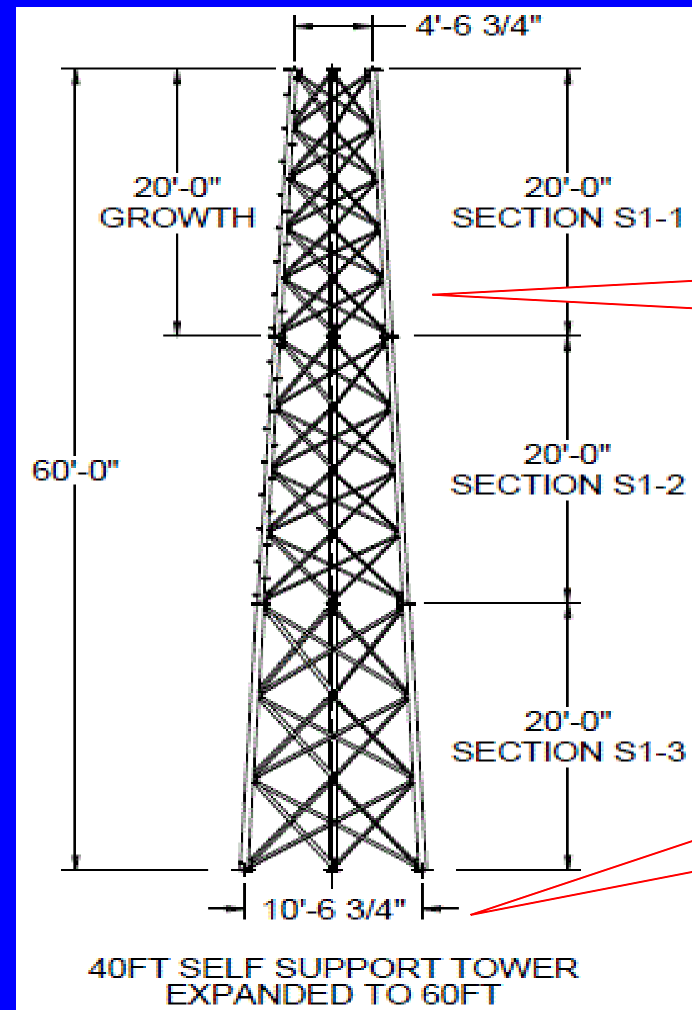
Typical Self-Supporting Tower – 40-foot Designed for Growth to 60 Feet

Tower Designs Provided by
Aero Solutions, LLC

AeroSolutions LLC
Optimizing Your Tower Infrastructure



Antenna Loading



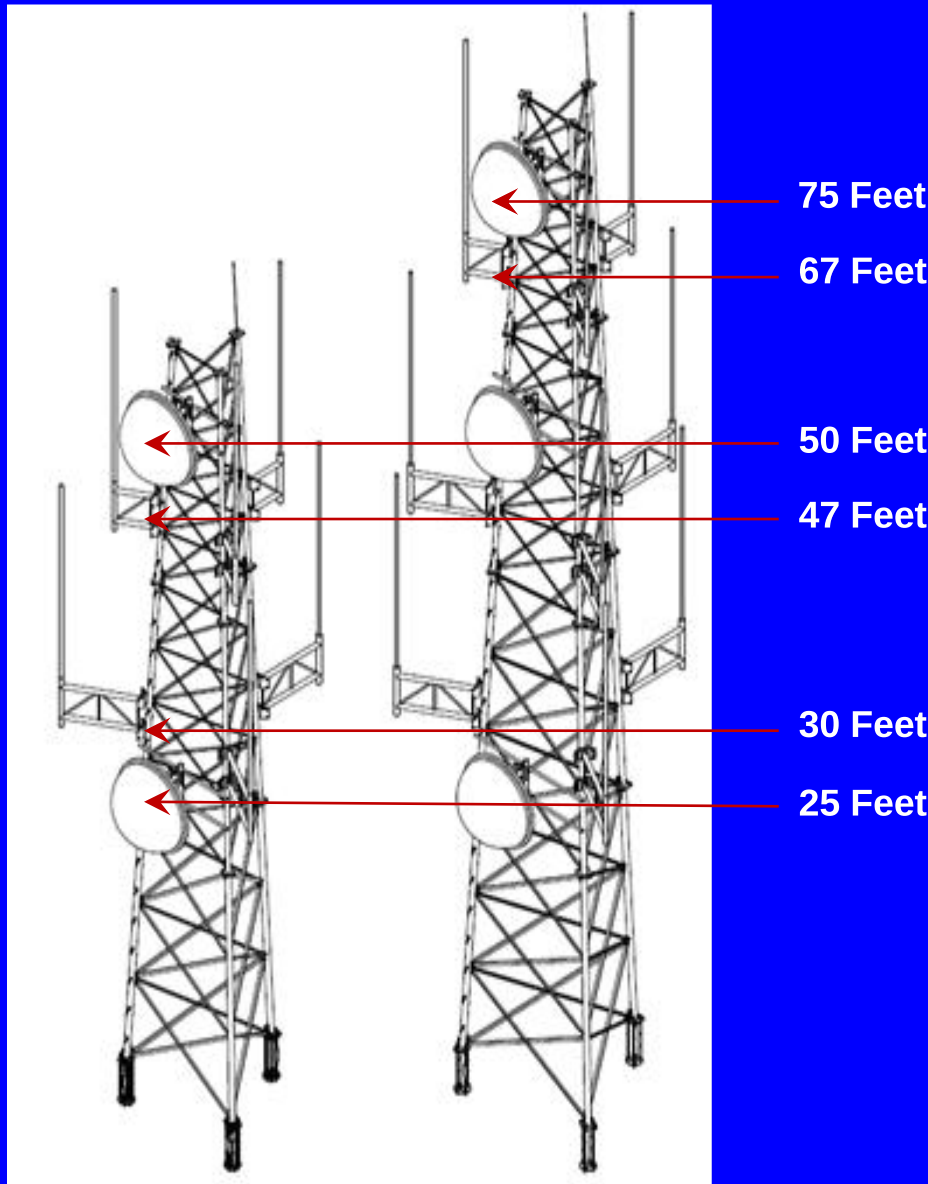
Tower Section Design

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

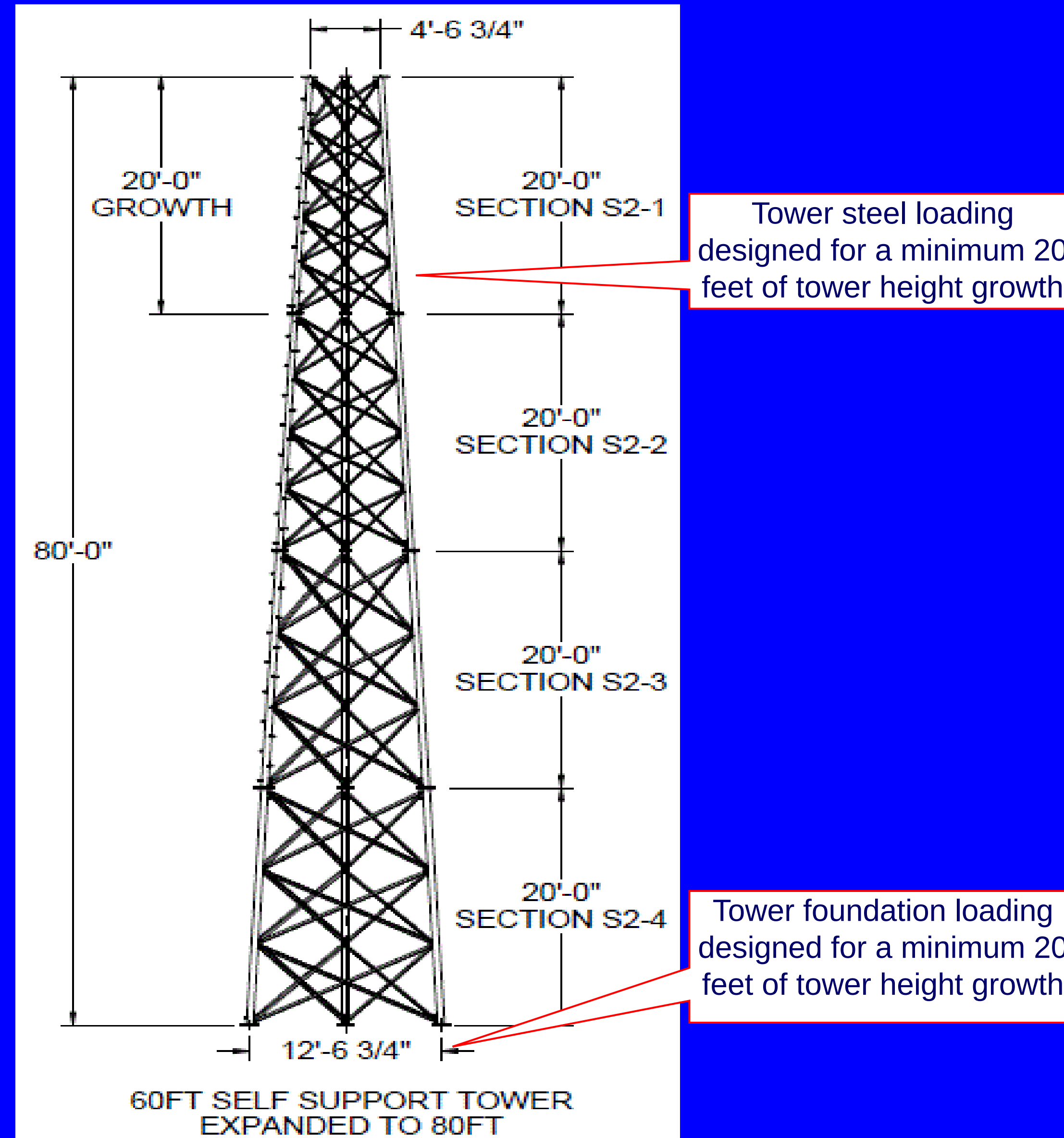
Typical Self-Supporting Tower – 60-foot Designed for Growth to 80 Feet

Tower Designs Provided by
Aero Solutions, LLC

AeroSolutions LLC
Optimizing Your Tower Infrastructure



Antenna Loading



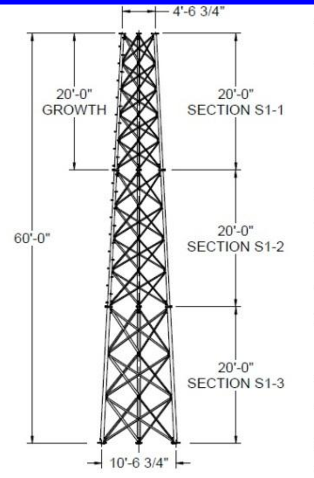
Tower Section Design

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

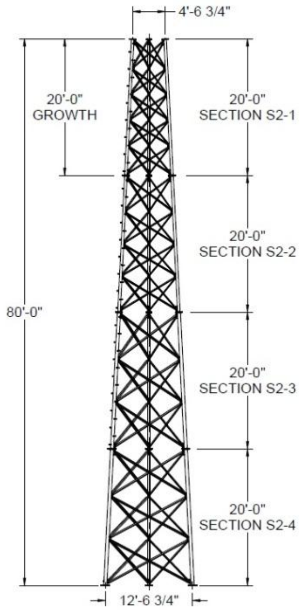
Typical Self-Supporting Tower Assemblies

Tower Design Drawing # 371-10-001-S2 - Example Not For Construction

Tower Designs Provided by
Aero Solutions, LLC



40FT SELF SUPPORT TOWER EXPANDED TO 60FT



60FT SELF SUPPORT TOWER EXPANDED TO 80FT

SELF-SUPPORTING LATTICE TOWER ASSEMBLIES

TOWER NUMBER	TOWER HEIGHT	BASE SECTION	TOWER WIDTH		NO ICE			WITH SOLID ICE			WITH RIME ICE
			TOP	BOTTOM	MOMENT (FT-KIP)	SHEAR (KIP)	WEIGHT (KIP)	MOMENT (FT-KIP)	SHEAR (KIP)	WEIGHT (KIP)	WEIGHT (KIP)
S1-40	40'	S1-3	6'-6 3/4"	10'-6 3/4"	494	21.8	5.6	170	7.3	30.6	561
S1-60	60'	S1-3	4'-6 3/4"	10'-6 3/4"	1175	35.5	7.9	412	12.1	47.2	900
S2-60	60'	S2-4	6'-6 3/4"	12'-6 3/4"	1423	44.6	11.5	477	14.7	59.1	1018
S2-80	80'	S2-4	4'-6 3/4"	12'-6 3/4"	2561	64.4	14.2	910	22.3	82.6	1477

SELF-SUPPORTING LATTICE TOWER SECTIONS

SECTION NUMBER	TOP WIDTH	BOTTOM WIDTH	LEG	PANELS	DIAGONAL	HORIZONTAL	FLANGE PLATE		FLANGE BOLTS	BRACE BOLTS	WEIGHT		
							TOP	BOTTOM			LEGS	BRACING	TOTAL
S1-1	4'-6 3/4"	6'-6 3/4"	P 2.375" OD x 0.154"	5	L 1 1/2" x 1 1/2" x 3/16"	L 2" x 2" x 3/16"	3/4" x 6 1/2" SQ.	3/4" x 6 1/2" SQ.	(12) 3/4" A325N	(75) 1/2" A325X	384 #	356 #	740 #
S1-2	6'-6 3/4"	8'-6 3/4"	P 3.500" OD x 0.216"	4	L 2 1/2" x 2 1/2" x 3/16"	L 2" x 2" x 3/16"	1" x 6 1/2" SQ.	1 1/4" x 11 1/4" DIA.	(12) 3/4" A325N	(60) 5/8" A325X	594 #	655 #	1249 #
S1-3	8'-6 3/4"	10'-6 3/4"	P 5.563" OD x 0.258"	3	L 2 1/2" x 2 1/2" x 3/16"	---	1 1/4" x 11 1/4" DIA.	1 1/4" x 11 1/4" DIA.	(24) 3/4" A325N	(45) 5/8" A325X	1133 #	1086 #	2219 #
S2-1	4'-6 3/4"	6'-6 3/4"	P 2.375" OD x 0.154"	5	L 1 1/2" x 1 1/2" x 3/16"	L 2" x 2" x 3/16"	3/4" x 6 1/2" SQ.	3/4" x 6 1/2" SQ.	(12) 3/4" A325N	(75) 1/2" A325X	384 #	356 #	740 #
S2-2	6'-6 3/4"	8'-6 3/4"	P 3.500" OD x 0.216"	4	L 2 1/2" x 2 1/2" x 3/16"	L 2" x 2" x 3/16"	1" x 6 1/2" SQ.	1 1/4" x 11 1/4" DIA.	(12) 3/4" A325N	(60) 5/8" A325X	594 #	655 #	1249 #
S2-3	8'-6 3/4"	10'-6 3/4"	P 5.563" OD x 0.258"	3	L 3 1/2" x 3 1/2" x 1/4"	---	1 1/4" x 11 1/4" DIA.	1 1/4" x 11 1/4" DIA.	(24) 3/4" A325N	(45) 5/8" A325X	1133 #	1086 #	2219 #
S2-4	10'-6 3/4"	12'-6 3/4"	P 6.625" OD x 0.375"	3	L 3 1/2" x 3 1/2" x 1/4"	---	1 1/4" x 11 1/4" DIA.	1 1/4" x 11 1/4" DIA.	(24) 3/4" A325N	(45) 3/4" A325X	1775 #	1262 #	3037 #

SELF-SUPPORTING LATTICE TOWER ANTENNA LOADING

TOWER	ANTENNA			MOUNT			LINE	
	ELEV. *	QTY.	DESCRIPTION	ELEV.*	QTY.	DESCRIPTION	QTY.	DESCRIPTION
S1-40	30'	3	ANDREW DB224-C	28'-9"	3	6' STANDOFF MOUNT (120 DEG. SEPARATION BETWEEN MOUNTS)	3	7/8" COAX
	25'	1	2 M SOLID DISH WITH RADOME	25'	1	2' STANDOFF MOUNT ON 7' FACE MOUNTED CROSS ARMS	1	7/8" COAX
S1-60	55'	1	2 M SOLID DISH WITH RADOME	55'	1	2' STANDOFF MOUNT ON 7' FACE MOUNTED CROSS ARMS	1	7/8" COAX
	47'	3	ANDREW DB224-C	45'-9"	3	3' STANDOFF MOUNT (120 DEG. SEPARATION BETWEEN MOUNTS)	3	7/8" COAX
	30'	3	ANDREW DB224-C	28'-9"	3	6' STANDOFF MOUNT (120 DEG. SEPARATION BETWEEN MOUNTS)	3	7/8" COAX
	25'	1	2 M SOLID DISH WITH RADOME	25'	1	2' STANDOFF MOUNT ON 7' FACE MOUNTED CROSS ARMS	1	7/8" COAX
S2-60	55'	1	2 M SOLID DISH WITH RADOME	55'	1	2' STANDOFF MOUNT ON 7' FACE MOUNTED CROSS ARMS	1	7/8" COAX
	47'	3	ANDREW DB224-C	45'-9"	3	3' STANDOFF MOUNT (120 DEG. SEPARATION BETWEEN MOUNTS)	3	7/8" COAX
	30'	3	ANDREW DB224-C	28'-9"	3	6' STANDOFF MOUNT (120 DEG. SEPARATION BETWEEN MOUNTS)	3	7/8" COAX
	25'	1	2 M SOLID DISH WITH RADOME	25'	1	2' STANDOFF MOUNT ON 7' FACE MOUNTED CROSS ARMS	1	7/8" COAX
S2-80	75'	1	2 M SOLID DISH WITH RADOME	75'	1	2' STANDOFF MOUNT ON 7' FACE MOUNTED CROSS ARMS	1	7/8" COAX
	67'	3	ANDREW DB224-C	65'-9"	3	3' STANDOFF MOUNT (120 DEG. SEPARATION BETWEEN MOUNTS)	3	7/8" COAX
	55'	1	2 M SOLID DISH WITH RADOME	55'	1	2' STANDOFF MOUNT ON 7' FACE MOUNTED CROSS ARMS	1	7/8" COAX
	47'	3	ANDREW DB224-C	45'-9"	3	3' STANDOFF MOUNT (120 DEG. SEPARATION BETWEEN MOUNTS)	3	7/8" COAX
	30'	3	ANDREW DB224-C	28'-9"	3	6' STANDOFF MOUNT (120 DEG. SEPARATION BETWEEN MOUNTS)	3	7/8" COAX
	25'	1	2 M SOLID DISH WITH RADOME	25'	1	2' STANDOFF MOUNT ON 7' FACE MOUNTED CROSS ARMS	1	7/8" COAX

* ELEVATIONS LISTED FOR BOTTOM OF OMNI/DIPOLE ANTENNAS AND CENTERLINES OF ALL OTHER ANTENNAS AND MOUNTS.

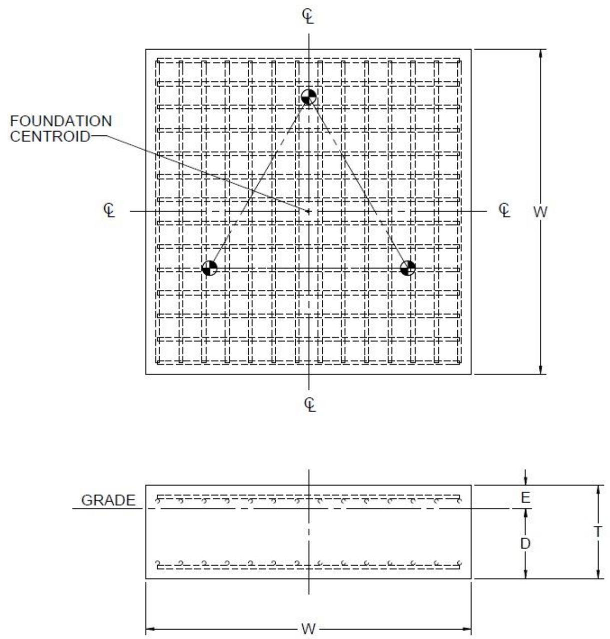
PRELIMINARY DRAWING NOT FOR CONSTRUCTION

Typical Self-Supporting Tower Foundation Designs

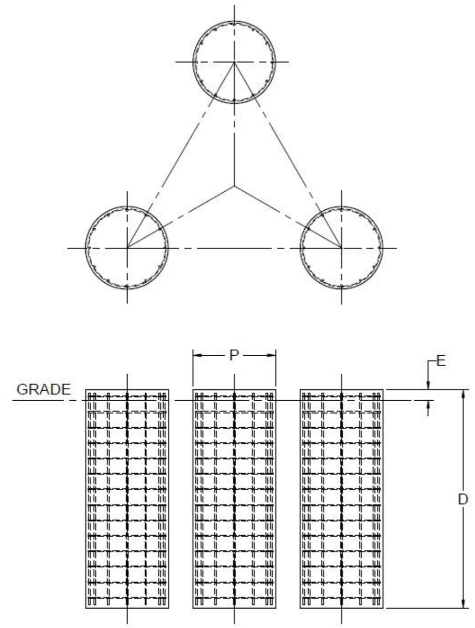
Tower Design Drawing # 371-10-001-F2 - Example Not For Construction

Tower Designs Provided by
Aero Solutions, LLC

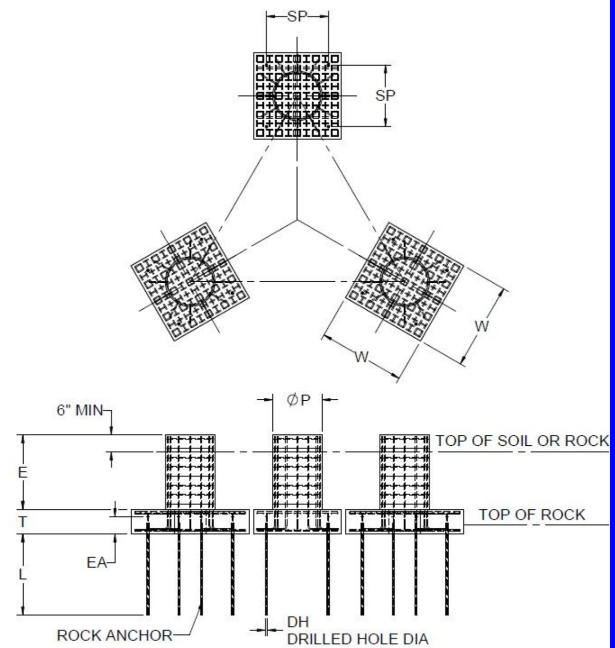
AeroSolutions LLC
Optimizing Your Tower Infrastructure



SELF SUPPORT TOWER MAT FOUNDATION



SELF SUPPORT TOWER DRILLED PIER FOUNDATION



SELF SUPPORT TOWER PAD W/ ROCK ANCHOR FOUNDATION

SELF-SUPPORTING LATTICE TOWER FOUNDATIONS

TOWER DESIGN	SOIL COND.	ANCHOR ROD ASSY.	MAT FOUNDATION W	MAT FOUNDATION D	MAT FOUNDATION T	MAT FOUNDATION E	MAT FOUNDATION HOR. BARS (PER DIR. PER LAYER)	MAT FOUNDATION CONC. VOL.	DRILLED PIER FOUNDATION D	DRILLED PIER FOUNDATION E	DRILLED PIER FOUNDATION P	DRILLED PIER FOUNDATION VERT. BARS (PER FND.)	DRILLED PIER FOUNDATION CONC. VOL. (3 FND.)
S1-40	SAND	A	13' - 6"	5'	5' - 6"	6"	17 #7	37.1 CU YD	19'	6"	2' - 6"	9 #8	10.6 CU YD
S1-40	CLAY	A	13' - 6"	5'	5' - 6"	6"	17 #7	37.1 CU YD	19'	6"	2' - 6"	9 #8	10.6 CU YD
S1-40	ROCK	A	---	---	---	---	---	---	---	---	---	---	---
S1-60	SAND	A	18' - 6"	5'	5' - 6"	6"	22 #7	69.7 CU YD	30'	6"	3' - 6"	18 #8	32.6 CU YD
S1-60	CLAY	A	18' - 6"	5'	5' - 6"	6"	22 #7	69.7 CU YD	30'	6"	3' - 6"	18 #8	32.6 CU YD
S1-60	ROCK	A	---	---	---	---	---	---	---	---	---	---	---
S2-60	SAND	B	19' - 6"	5'	5' - 6"	6"	24 #7	77.5 CU YD	31'	6"	3' - 6"	18 #8	33.7 CU YD
S2-60	CLAY	B	19' - 6"	5'	5' - 6"	6"	24 #7	77.5 CU YD	31'	6"	3' - 6"	18 #8	33.7 CU YD
S2-60	ROCK	B	---	---	---	---	---	---	---	---	---	---	---
S2-80	SAND	B	24'	5'	5' - 6"	6"	29 #7	117.3 CU YD	48'	6"	4'	23 #8	67.7 CU YD
S2-80	CLAY	B	24'	5'	5' - 6"	6"	29 #7	117.3 CU YD	48'	6"	4'	23 #8	67.7 CU YD
S2-80	ROCK	B	---	---	---	---	---	---	---	---	---	---	---

TOWER DESIGN	SOIL COND.	INDIVIDUAL PAD WITH ROCK ANCHORS W	T	D	P	E	ROCK ANCHOR	ANCHOR PROOF LOAD	ANCHOR LOCKOFF LOAD	DH	SP	EA	L	HOR. BARS (PER DIR., PER LAYER, PER FND.)	VERT. BARS (PER FND.)	CONC. VOL. (3 FND.)
S1-40	SAND	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
S1-40	CLAY	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
S1-40	ROCK	6'	3'	6" MIN	3'	2' MIN/5' MAX	4 #6 (3/4" ϕ) x 12'-9"	16 KIP	14 KIP	3"	3' - 6"	2' - 5"	10'	6 #7	14 #8	15.9 CU YD
S1-60	SAND	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
S1-60	CLAY	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
S1-60	ROCK	6'	3'	6" MIN	3'	2' MIN/5' MAX	4 #7 (7/8" ϕ) x 14'-9"	38 KIP	32 KIP	3 1/2"	3' - 6"	2' - 5"	12'	6 #7	14 #8	15.9 CU YD
S2-60	SAND	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
S2-60	CLAY	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
S2-60	ROCK	6'	3'	6" MIN	3'	2' MIN/5' MAX	4 #7 (7/8" ϕ) x 14'-9"	39 KIP	32 KIP	3 1/2"	3' - 6"	2' - 5"	12'	6 #7	14 #8	15.9 CU YD
S2-80	SAND	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
S2-80	CLAY	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
S2-80	ROCK	6'	3'	6" MIN	3'	2' MIN/5' MAX	4 #11 (1-3/8" ϕ) x 18'-9"	70 KIP	58 KIP	4"	3' - 6"	2' - 5"	16'	6 #7	14 #8	15.9 CU YD

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Typical Monopole Tower – Antenna Loading Assumptions

Tower Designs Provided by
Aero Solutions, LLC

The following antennas and mounting heights are used in the typical design for monopole towers:

- **40-foot flanged monopole designed for growth to 60 feet**

  Designed antenna loading parameters

  - One 2-meter microwave dish mounted 25 feet above grade level (AGL)
  - Three DB224-C omnidirectional antenna mounted 30 feet AGL

- **60-foot Flanged Monopole designed for growth to 80 feet**

  Designed antenna loading parameters:

  - One 2-meter microwave dish mounted 25 feet AGL
  - Three DB224-C omnidirectional antenna mounted 30 feet AGL
  - Three DB224-C omnidirectional antenna mounted 47 feet AGL
  - One 2-meter microwave dish mounted 55 feet AGL

- **80-foot Flanged Monopole**

  Designed antenna loading parameters

  - One 2-meter microwave dish mounted 25 feet AGL
  - Three DB224-C omnidirectional antenna mounted 30 feet AGL
  - Three DB224-C omnidirectional antenna mounted 47 feet AGL
  - One 2-meter microwave dish mounted 55 feet AGL
  - Three DB224-C omnidirectional antenna mounted 67 feet AGL
  - One 2-meter microwave dish mounted 75 feet AGL

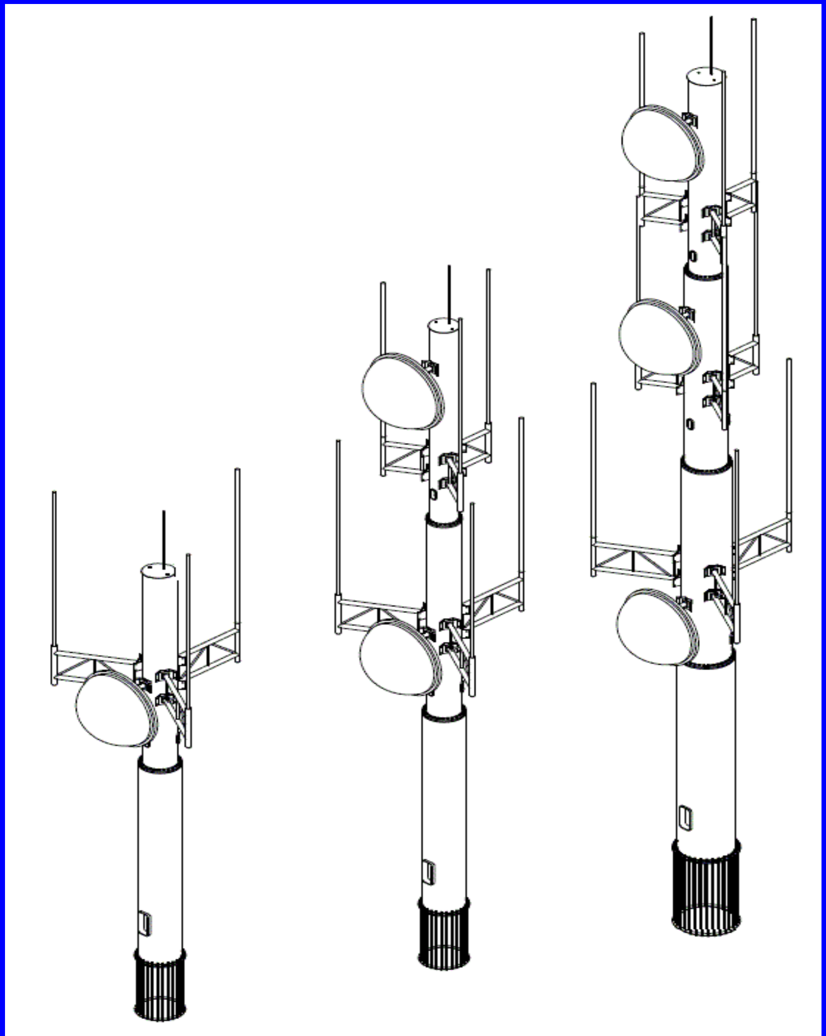
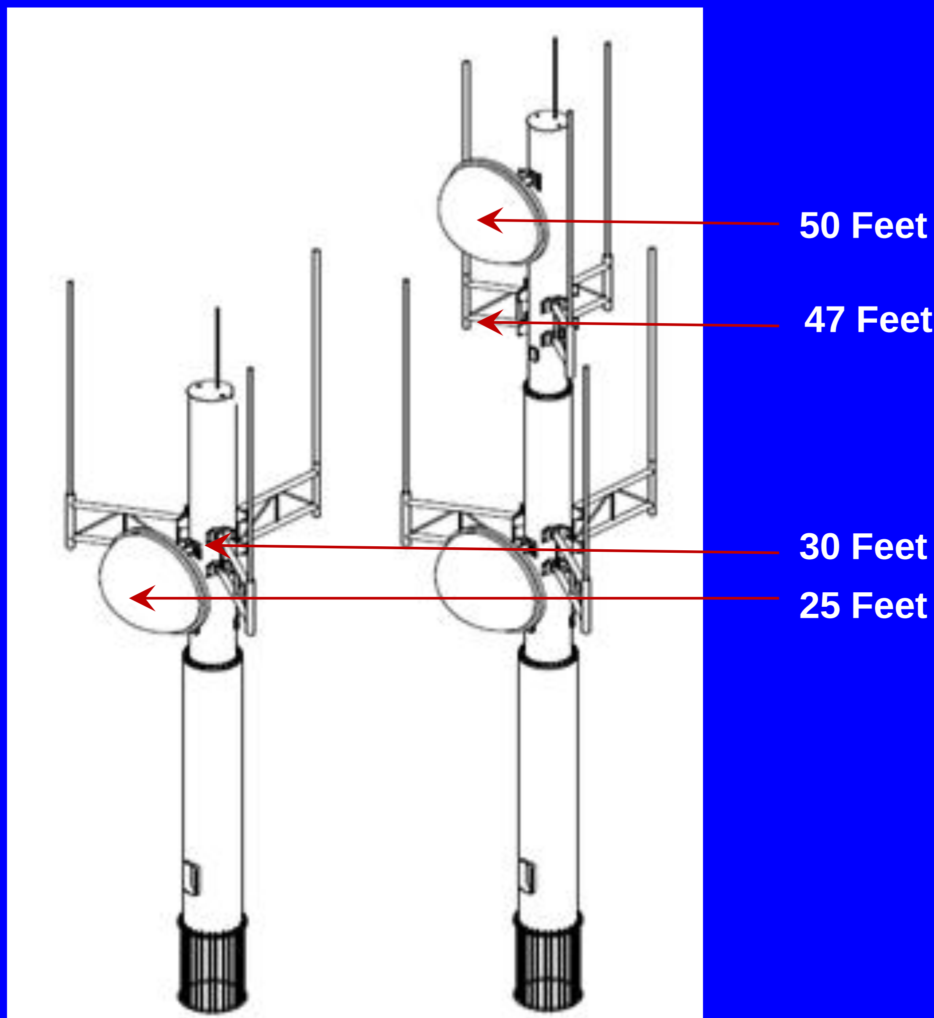


Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

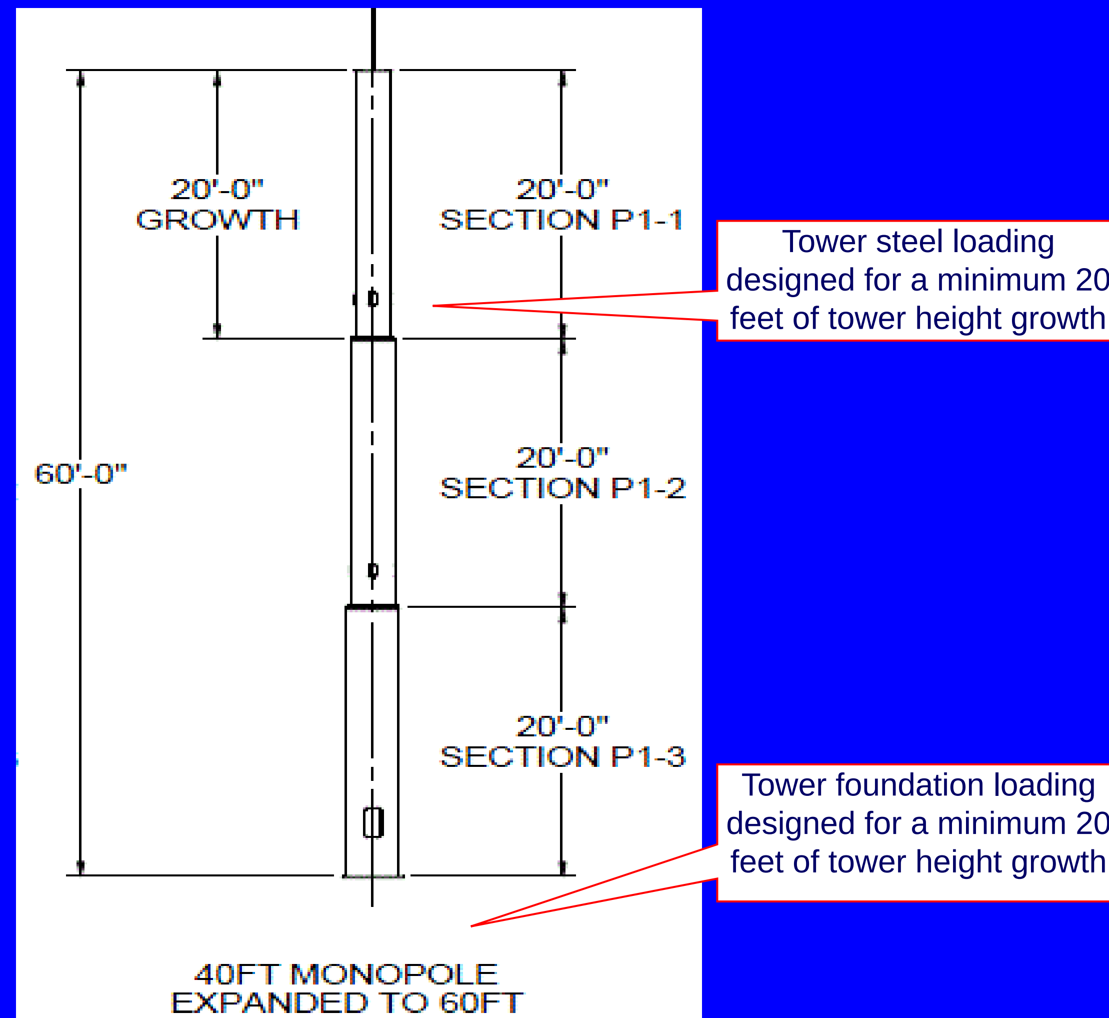
Typical Flanged Monopole – 40-foot Designed for Growth to 60 Feet

Tower Designs Provided by
Aero Solutions, LLC

AeroSolutions LLC
Optimizing Your Tower Infrastructure



Antenna Loading



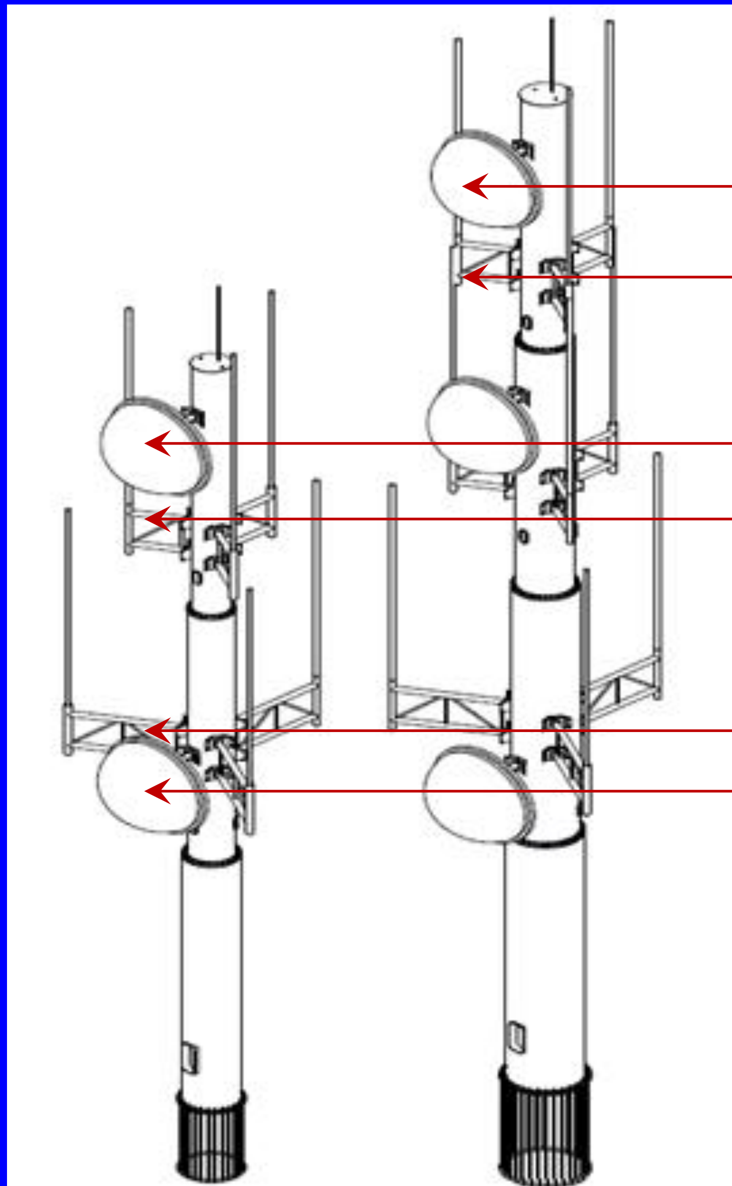
Tower Section Design

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

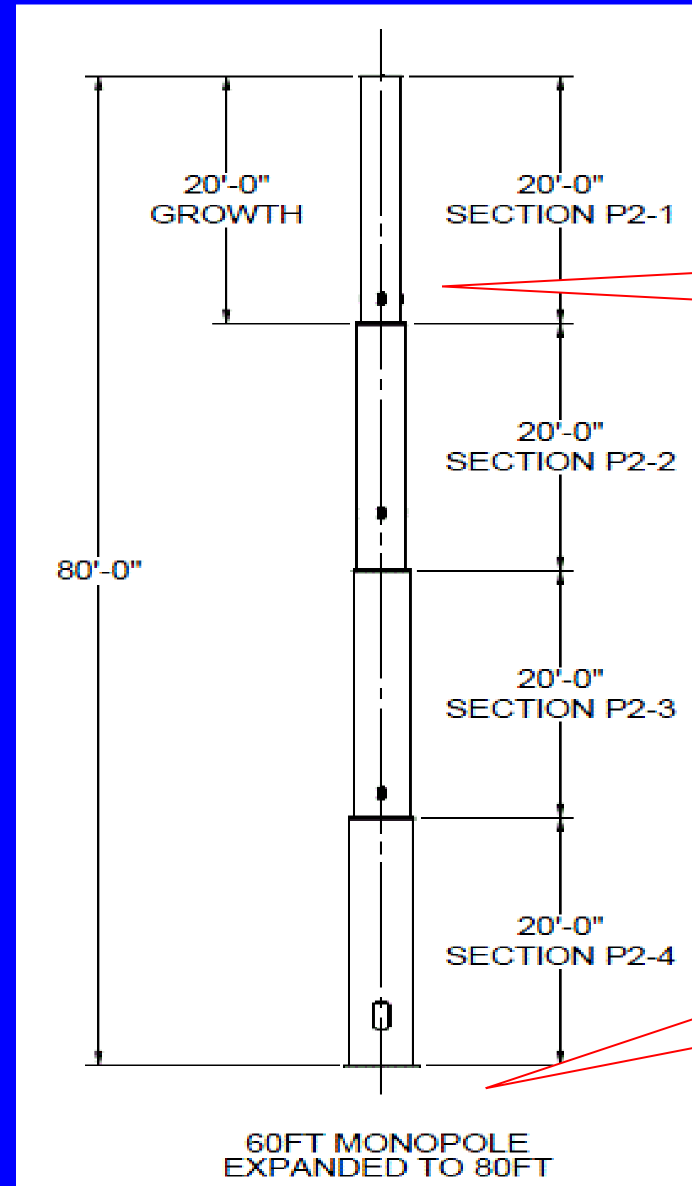
Typical Flanged Monopole – 60-foot Designed for Growth to 80 Feet

Tower Designs Provided by
Aero Solutions, LLC

AeroSolutions LLC
Optimizing Your Tower Infrastructure



Antenna Loading



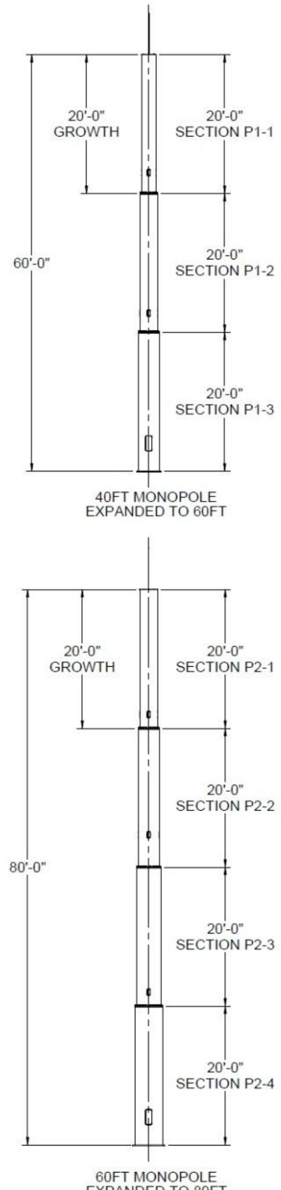
Tower Section Design

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Typical Monopole Tower Assemblies

Tower Design Drawing # 371-10-001-S4 - Example Not For Construction

Tower Designs Provided by
Aero Solutions, LLC



FLANGED MONOPOLE TOWER ASSEMBLIES

TOWER NUMBER	TOWER HEIGHT	BASE SECTION	NO ICE			WITH SOLID ICE			WITH RIME ICE
			MOMENT (FT-KIP)	SHEAR (KIP)	WEIGHT (KIP)	MOMENT (FT-KIP)	SHEAR (KIP)	WEIGHT (KIP)	WEIGHT (KIP)
P1-40	40'	P1-3	458	19.3	8.7	197	7.6	21.2	156
P1-60	60'	P1-3	1162	32.5	12.7	472	12.7	32.3	199
P2-60	60'	P2-4	1350	38.3	17.9	528	14.3	40.4	268
P2-80	80'	P2-4	2457	53.4	22.6	955	20.1	53.1	366

FLANGED MONOPOLE TOWER SECTIONS

SECTION NUMBER	POLE DIAMETER	WALL THICKNESS	TOP FLANGE					BOTTOM FLANGE					SECTION WEIGHT
			THICKNESS	INNER DIAMETER	BOLT CIRCLE DIAMETER	NUMBER OF BOLTS	BOLT DIAMETER	THICKNESS	OUTER DIAMETER	BOLT CIRCLE DIAMETER	NUMBER OF BOLTS	BOLT DIAMETER	
P1-1	24"	3/8"						1-1/2"	30"	27"	22	1"	1990 #
P1-2	30"	3/8"	1-1/2"	24"	27"	22	1"	1-1/2"	36"	33"	26	1"	2590 #
P1-3	36"	3/8"	1-1/2"	30"	33"	26	1"	1-1/2"	42"	39"	28	1"	3110 #
P2-1	30"	3/8"						1-1/2"	36"	33"	26	1"	2490 #
P2-2	36"	3/8"	1-1/2"	30"	33"	26	1"	1-1/2"	42"	39"	32	1"	3110 #
P2-3	42"	3/8"	1-1/2"	36"	39"	32	1"	1-1/2"	48"	45"	36	1"	3630 #
P2-4	48"	1/2"	1-1/2"	42"	45"	36	1"	1-1/2"	56"	52"	32	1-1/4"	5470 #

FLANGED MONOPOLE TOWER ANTENNA LOADING

TOWER	ANTENNA			MOUNT			LINE	
	ELEV. *	QTY.	DESCRIPTION	ELEV. *	QTY.	DESCRIPTION	QTY.	DESCRIPTION
P1-40	30'	3	ANDREW DB224-C	28'-9"	3	6' STANDOFF MOUNT (120 DEG. SEPARATION BETWEEN MOUNTS)	3	7/8" COAX
	25'	1	2 M SOLID DISH WITH RADOME	25'	1	2' STANDOFF MOUNT	1	7/8" COAX
P1-60	55'	1	2 M SOLID DISH WITH RADOME	55'	1	2' STANDOFF MOUNT	1	7/8" COAX
	47'	3	ANDREW DB224-C	45'-9"	3	3' STANDOFF MOUNT (120 DEG. SEPARATION BETWEEN MOUNTS)	3	7/8" COAX
	30'	3	ANDREW DB224-C	28'-9"	3	6' STANDOFF MOUNT (120 DEG. SEPARATION BETWEEN MOUNTS)	3	7/8" COAX
	25'	1	2 M SOLID DISH WITH RADOME	25'	1	2' STANDOFF MOUNT	1	7/8" COAX
P2-60	55'	1	2 M SOLID DISH WITH RADOME	55'	1	2' STANDOFF MOUNT	1	7/8" COAX
	50'	3	ANDREW DB224-C	48'-9"	3	3' STANDOFF MOUNT (120 DEG. SEPARATION BETWEEN MOUNTS)	3	7/8" COAX
	30'	3	ANDREW DB224-C	28'-9"	3	6' STANDOFF MOUNT (120 DEG. SEPARATION BETWEEN MOUNTS)	3	7/8" COAX
	25'	1	2 M SOLID DISH WITH RADOME	25'	1	2' STANDOFF MOUNT	1	7/8" COAX
P2-80	75'	1	2 M SOLID DISH WITH RADOME	75'	1	2' STANDOFF MOUNT	1	7/8" COAX
	67'	3	ANDREW DB224-C	65'-9"	3	3' STANDOFF MOUNT (120 DEG. SEPARATION BETWEEN MOUNTS)	3	7/8" COAX
	55'	1	2 M SOLID DISH WITH RADOME	55'	1	2' STANDOFF MOUNT	1	7/8" COAX
	50'	3	ANDREW DB224-C	48'-9"	3	3' STANDOFF MOUNT (120 DEG. SEPARATION BETWEEN MOUNTS)	3	7/8" COAX
	30'	3	ANDREW DB224-C	28'-9"	3	6' STANDOFF MOUNT (120 DEG. SEPARATION BETWEEN MOUNTS)	3	7/8" COAX
	25'	1	2 M SOLID DISH WITH RADOME	25'	1	2' STANDOFF MOUNT	1	7/8" COAX

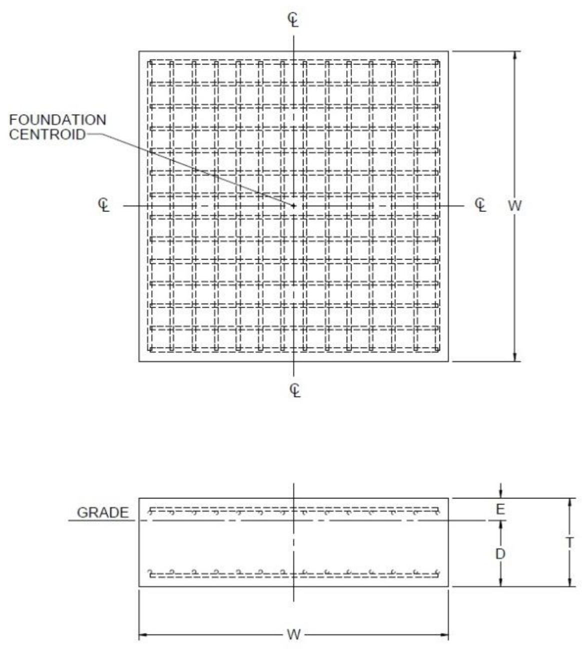
* ELEVATIONS LISTED FOR BOTTOM OF OMNI/DIPOLE ANTENNAS AND CENTERLINES OF ALL OTHER ANTENNAS AND MOUNTS.

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

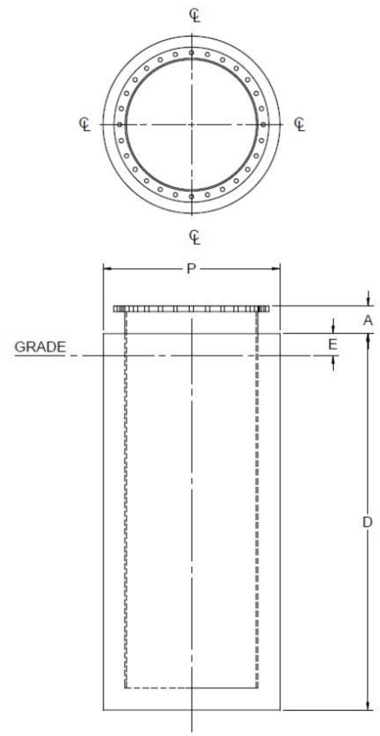
Typical Monopole Tower Foundation Designs

Tower Design Drawing # 371-10-001-F3 - Example Not For Construction

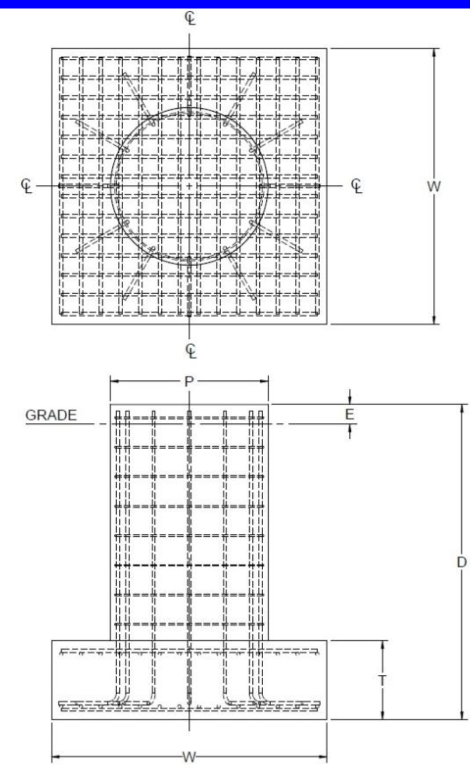
Tower Designs Provided by
Aero Solutions, LLC



MONOPOLE MAT FOUNDATION



MONOPOLE EMBEDDED FOUNDATION



MONOPOLE PAD & PIER FOUNDATION

FLANGED MONOPOLE TOWER FOUNDATIONS

TOWER DESIGN	SOIL COND.	ANCHOR ROD ASSY.	MAT FOUNDATION W	MAT FOUNDATION D	MAT FOUNDATION T	MAT FOUNDATION E	MAT FOUNDATION HOR. BARS (PER DIR., PER LAYER)	MAT FOUNDATION CONC. VOL.	EMBEDDED POLE FOUNDATION D	EMBEDDED POLE FOUNDATION E	EMBEDDED POLE FOUNDATION A	EMBEDDED POLE FOUNDATION P	EMBEDDED POLE FOUNDATION CONC. VOL.	PIER AND PAD FOUNDATION W	PIER AND PAD FOUNDATION D	PIER AND PAD FOUNDATION T	PIER AND PAD FOUNDATION E	PIER AND PAD FOUNDATION P	PIER AND PAD FOUNDATION HOR. BARS (PER DIR., PER LAYER)	PIER AND PAD FOUNDATION VERT. BARS	PIER AND PAD FOUNDATION TIES	PIER AND PAD FOUNDATION CONC. VOL.
P1-40	SAND	A	13'	5'	5' - 6"	6"	16 #7	34.4 cu yd	19' - 6"	6"	6"	4'	9.3 cu yd	14' - 6"	8'	2'	6"	5'	15 #6	29 #9	15 #4	20.3 cu yd
P1-40	CLAY	A	13'	5'	5' - 6"	6"	16 #7	34.4 cu yd	15'	6"	6"	4'	7.2 cu yd	14' - 6"	8'	2'	6"	5'	15 #6	29 #9	15 #4	20.3 cu yd
P1-40	ROCK	A	13'	5'	5' - 6"	6"	16 #7	34.4 cu yd	---	---	---	---	---	11'	8'	2'	6"	5'	12 #6	15 #9	7 #4	13.7 cu yd
P1-60	SAND	A	18' - 6"	5'	5' - 6"	6"	22 #7	69.7 cu yd	25' - 6"	6"	6"	4'	12.1 cu yd	19'	8'	2'	6"	5'	25 #6	29 #9	15 #4	31.5 cu yd
P1-60	CLAY	A	18' - 6"	5'	5' - 6"	6"	22 #7	69.7 cu yd	20'	6"	6"	4'	9.5 cu yd	19'	8'	2'	6"	5'	25 #6	29 #9	15 #4	31.5 cu yd
P1-60	ROCK	A	16'	5'	5' - 6"	6"	20 #7	52.1 cu yd	---	---	---	---	---	14' - 6"	8'	2'	6"	5'	24 #6	24 #9	7 #4	20.3 cu yd
P2-60	SAND	B	19'	5'	5' - 6"	6"	23 #7	73.5 cu yd	25'	6"	6"	5'	18.5 cu yd	20'	8'	2'	6"	6'	21 #7	42 #9	15 #4	36.4 cu yd
P2-60	CLAY	B	19'	5'	5' - 6"	6"	23 #7	73.5 cu yd	19' - 6"	6"	6"	5'	14.5 cu yd	20'	8'	2'	6"	6'	21 #7	42 #9	15 #4	36.4 cu yd
P2-60	ROCK	B	17'	5'	5' - 6"	6"	21 #7	58.9 cu yd	---	---	---	---	---	15' - 6"	8'	2'	6"	6'	19 #7	22 #9	7 #4	24.6 cu yd
P2-80	SAND	B	23' - 6"	5'	5' - 6"	6"	28 #7	112.5 cu yd	29' - 6"	6"	6"	5'	21.8 cu yd	24'	8'	2'	6"	6'	39 #7	42 #9	15 #4	49.5 cu yd
P2-80	CLAY	B	23' - 6"	5'	5' - 6"	6"	28 #7	112.5 cu yd	24'	6"	6"	5'	17.8 cu yd	24'	8'	2'	6"	6'	39 #7	42 #9	15 #4	49.5 cu yd
P2-80	ROCK	B	20' - 6"	5'	5' - 6"	6"	25 #7	85.6 cu yd	---	---	---	---	---	18' - 6"	8'	2'	6"	6'	37 #7	39 #9	7 #4	32.2 cu yd

Antenna Installation – Man-rated Antenna Standoff Brackets

Tower Designs Provided by
Aero Solutions, LLC

- The typical tower designs include the following antenna mounting brackets and RF cable sizes:
  - Omnidirectional antennas are fastened to the tower on 3-foot and 6-foot standoff brackets
  - Antenna standoff brackets are engineered to be “Man-rated” to support a minimum of 250 pounds
  - RF cables (coax) routed to each antenna are 7/8-inch diameter

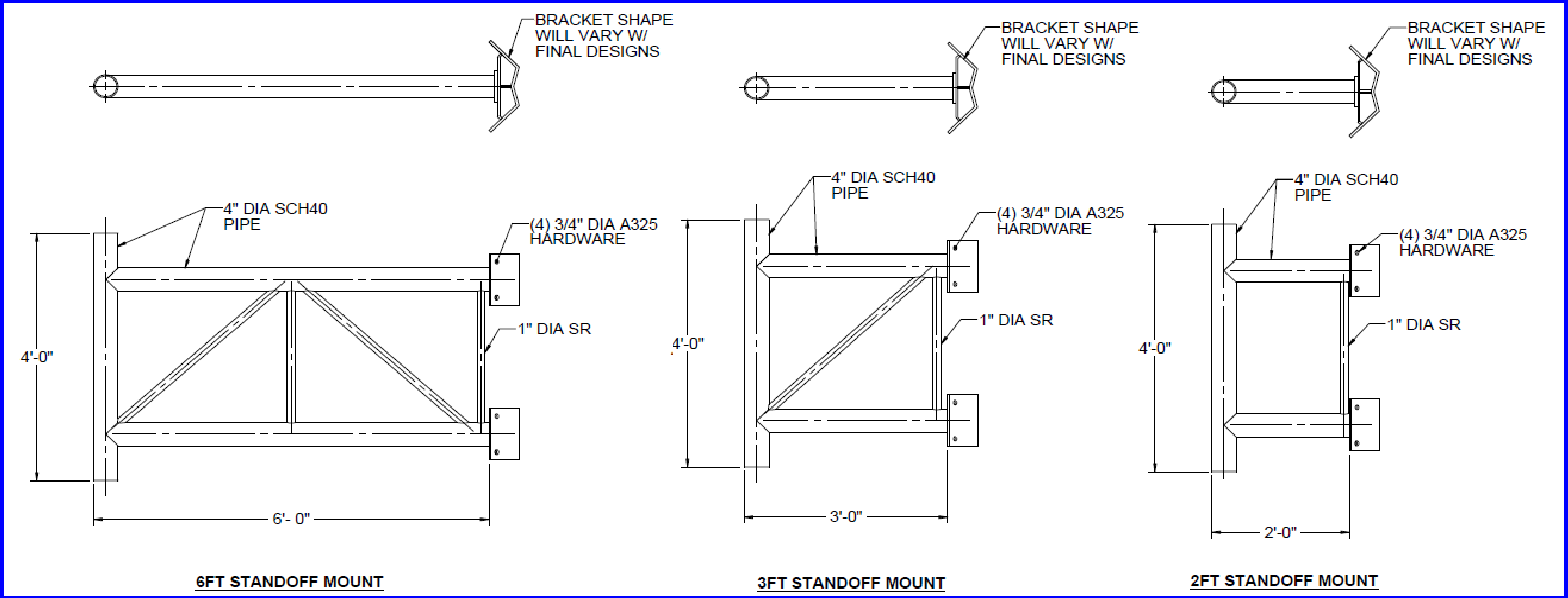


Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Existing Tower – Design Requirements

ANSI/EIA/TIA-222-G, Section 15 – Analysis of Existing Towers and Structures

Motorola R56 Standard 2.12.6 – Antenna and Dish Loading

- Though not included in the standard radio facility design specifications, Motorola R56 and ANSI/EIA/TIA-222 standards provide the minimum criteria for designing and installing antennas on existing towers and antenna supporting structures. Antenna loading requirements are one of the most critical aspects of tower design. Items considered for loading requirements include, but are not limited to, the following:
  - Antenna quantity, size, type, manufacturer, frequency, and elevation
  - Future antenna loading requirements
  - Transmission cable diameter and type
  - Sidearm length and location
  - Lighting requirements
  - Ice and wind loading
  - Climbing ladders and rest platforms
  - Miscellaneous optional equipment, such as ice shields
- A structural analysis must be performed by a qualified professional engineer whenever there is a change in the quantity, size, location, or type of antennas, transmission lines, or other tower-mounted equipment that differs from the original design or operational load of the tower. This must be accomplished to determine if the additional load can be safely supported. In order to determine if the existing or proposed load is acceptable, the tower member sizes, dimensions, connection, and materials must be analyzed. Data may be obtained by referencing the following details:
  - Previous stress and rigidity tests
  - Design and as-built structural and detailed site drawings
  - Tower specifications
  - Construction records
  - Field investigation

Aluminum Shelter with Articulating Antenna Mast

Section 13 34 18.13 – Aluminum Shelter with Articulating Antenna Mast

- Lightweight aluminum shelters are ideal for use on remote mountain tops, roof tops, and at existing tower bases. These units employ the Faraday Cage principle to shield sensitive digital communications equipment from the effects of radio frequency interference (RFI), electromagnetic interference (EMI), and electromagnetic pulse (EMP).
  - The lightweight shelter allows it to be delivered by helicopter to remote mountain-top facilities
  - Variable dimensions and antenna mast heights are available
  - The shelter may be installed on a concrete foundation or directly on the ground with ballast mounts. The ballast mounts are adjustable for leveling the shelter
  - Using ballast mounts eliminates excavation and concrete delivery for the foundation
  - The attached antenna mast articulates to the ground and eliminates tower climbing

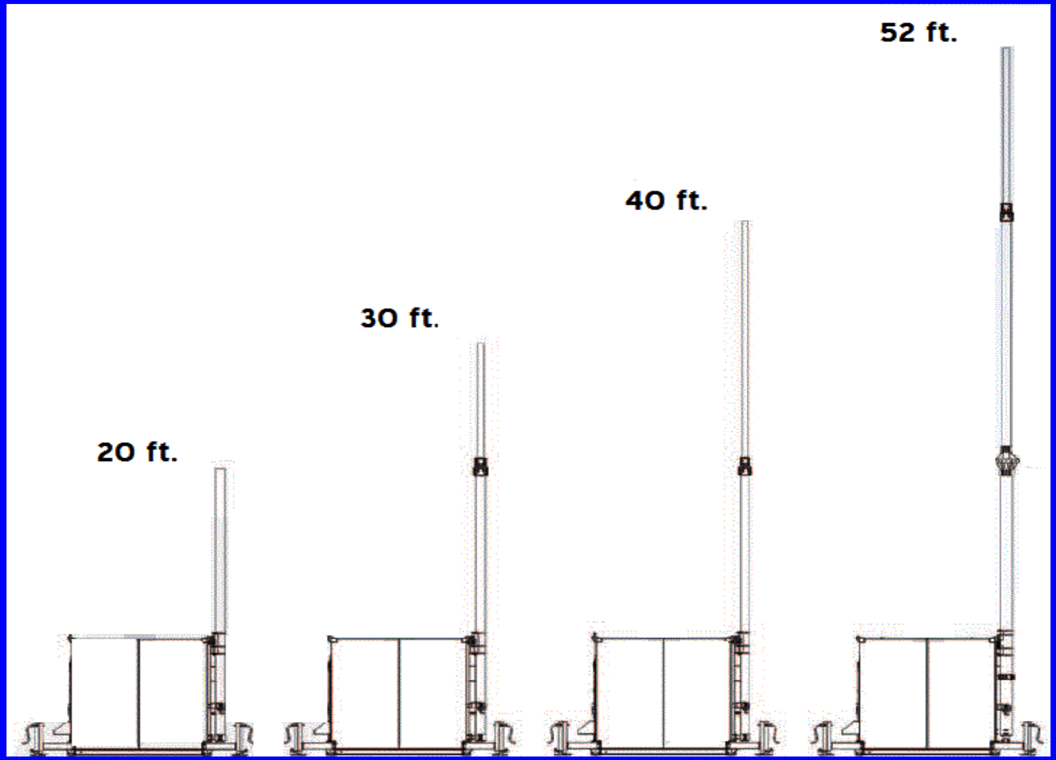


Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Aluminum Shelter with Articulating Antenna Mast – Design Variables

Section 13 34 18.13 – Aluminum Shelter with Articulating Antenna Mast

The specification for the shelter and attached antenna mast have multiple variables to customize the shelter for the radio facility. Click on the form image to open the PDF and enter the variables for the shelter. The shelter variable selections include the following:

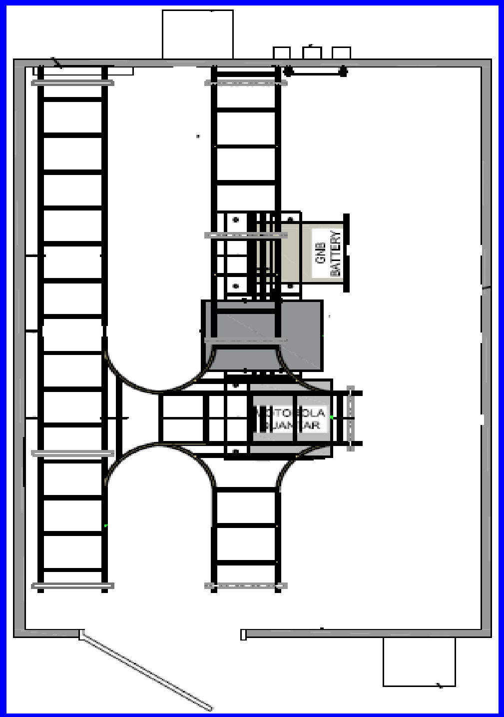
- Dimensions
- Exterior finish and color
- Wind loading
- Roof snow loading
- Live floor loading
- Battery loading
- Seismic design considerations
- Options for commercial and photovoltaic power distribution
- Air-conditioner size
- Cable ladder size
- RF cable entrance port size
- Options for equipment rack installation by the shelter vendor
- Antenna mast height
- Antenna mast structural design and loading requirements

Section 13 34 18.13 – Prefabricated Aluminum Shelter with Telescoping Mast				Variable Paragraph
Specifier Note	SPECIFIER NOTE: Concrete Foundations are optional. Shelters are to be designed with metal skids capable of placement directly on substantially level soil. If a Concrete Foundation is not required, Omit SECTION 13 34 23 – Prefabricated Shelter Foundation			
Specifier Note	SPECIFIER (2.1 C.5) : Choose Exterior Shelter Finish Color in paragraph 2.1 C.5.			
(2.1 C.5)	Shelter Exterior Color:	333		Section 13 34 18.13 (2.1.C.5)
Specifier Note	SPECIFIER: (2.2.A) Choose Shelter Size and Dimensions.			
(2.2.A)	Shelter Internal Width (ID):	33	Feet, Inches	Section 13 34 18.13 (2.2.A)
(2.2.A)	Shelter Internal Length (ID):		Feet, Inches	Section 13 34 18.13 (2.2.A)
(2.2.A)	Shelter Internal Height (ID):		Feet, Inches	Section 13 34 18.13 (2.2.A)
Specifier Note	SPECIFIER (2.2.B.1): Choose required shelter design Wind Load. SPECIFIER: (2.2.B.2): Choose required shelter design Roof Snow Load. SPECIFIER: (2.2.B.3): Choose required shelter UBS Seismic Zone. SPECIFIER: (2.2.B.4): Choose required shelter Exposure Category.			
(2.2.B.1)	Shelter Wind Load:	1	MPH	Section 13 34 18.13 (2.2.B.1)
(2.2.B.2)	Shelter Roof Snow Load:		PSF	Section 13 34 18.13 (2.2.B.2)
(2.2.B.3)	Shelter Seismic Design Zone (Max Ground Acceleration)	Zone 0 Zone 1 Zone 2A Zone 2B Zone 3 Zone 4	Zone 0 = (0.04g) Zone 1 = (0.08g) Zone 2A = (0.16g) Zone 2B = (0.20g) Zone 3 = (0..33g) Zone 4 = (0.5g)	Section 13 34 18.13 (2.2.B.3)
(2.2.B.4)	Shelter Exposure Category			Section 13 34 18.13 (2.2.B.4)
(2.2.E.2)	Shelter Live Floor Load:		PSF	Section 13 34 18.13 (2.2.E.2)
(2.2.E.2.a.1)	Battery Manufacturer:		MFR Name	Section 13 34 18.13 (2.2.E.2.a.1)
(2.2.E.2.a.2)	Battery Model Number:		MFR Part Number	Section 13 34 18.13 (2.2.E.2.a.2)
(2.2.E.2.a.3)	Battery Weight:		LBS	Section 13 34 18.13 (2.2.E.2.a.3)
(2.2.E.2.a.4)	Battery Base Width:		Inches	Section 13 34 18.13 (2.2.E.2.a.4)
(2.2.E.2.a.4)	Battery Base Length:		Inches	Section 13 34 18.13 (2.2.E.2.a.4)
Specifier Note	SPECIFIER: (2.4.A) Standard design is Ballast Mount as described in paragraph 2.4.A. If a concrete foundation is selected in paragraph 2.4.B, delete paragraph 2.4.A. SPECIFIER: (2.4.B) Delete the paragraph 2.4.B when a concrete foundation for the shelter is not required.			
(2.4.A)	Shelter Anchoring Type:			Section 13 34 18.13 (2.4.A)
(2.4.B)				Section 13 34 18.13 (2.4.B)
Specifier Note	SPECIFIER: (2.6) Air-Conditioning Is Optional: Air-Conditioners are not to be included on Renewable Energy Powered sites. Delete paragraph 2.6 when Air-Conditioning is not required. SPECIFIER: (2.6.A.1) Select the Air-conditioner size.			
(2.6.A.1)	Air-Conditioner Size:			Section 13 34 18.13 (2.6.A.1)
Specifier Note	SPECIFIER: (2.9 A.1) Choose cable ladder width in paragraph 2.9 A1.			
(2.9 A.1)	Cable Ladder Width:		Inches	Section 13 34 18.13 (2.9 A.1)
Specifier Note	SPECIFIER: (2.9.B.2) Modify RF entrance port quantity in paragraph 2.9B2 and quantity of shielded entry glands in 2.9.B.2.a.			
(2.9.B.2)	Quantity of Ports in the RF Cable Entrance Panel:		Quantity	Section 13 34 18.13 (2.9.B.2)
(2.9.B.2.a)	Quantity of Shielded Entry Glands:		Quantity	Section 13 34 18.13 (2.9.B.2.a)
Specifier Note	SPECIFIER: (2.10) Choose Antenna Mast Height in paragraph 2.10.A. Equipment cabinet is designed for a 20-foot mast max.			
(2.10.A)	Attached Antenna Mast Height:	20-foot attached mast 30-foot attached mast 40-foot attached mast 52-foot attached mast		Section 13 34 18.13 (2.10.A)

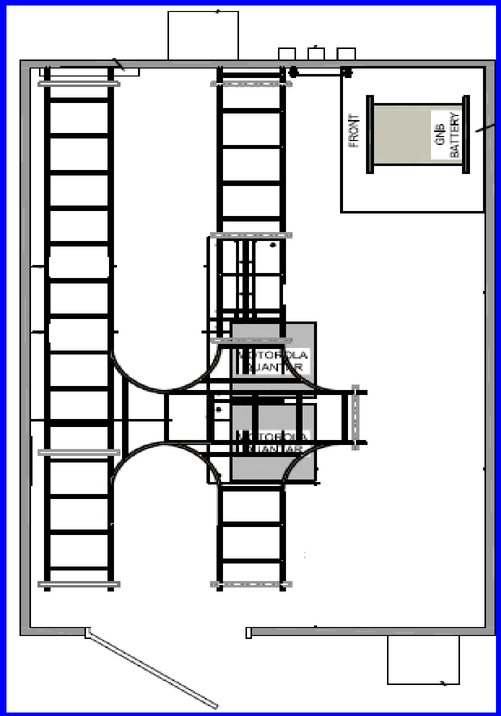
Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Typical 8-foot wide, 12-foot long, Aluminum Shelter with Articulating Antenna Mast

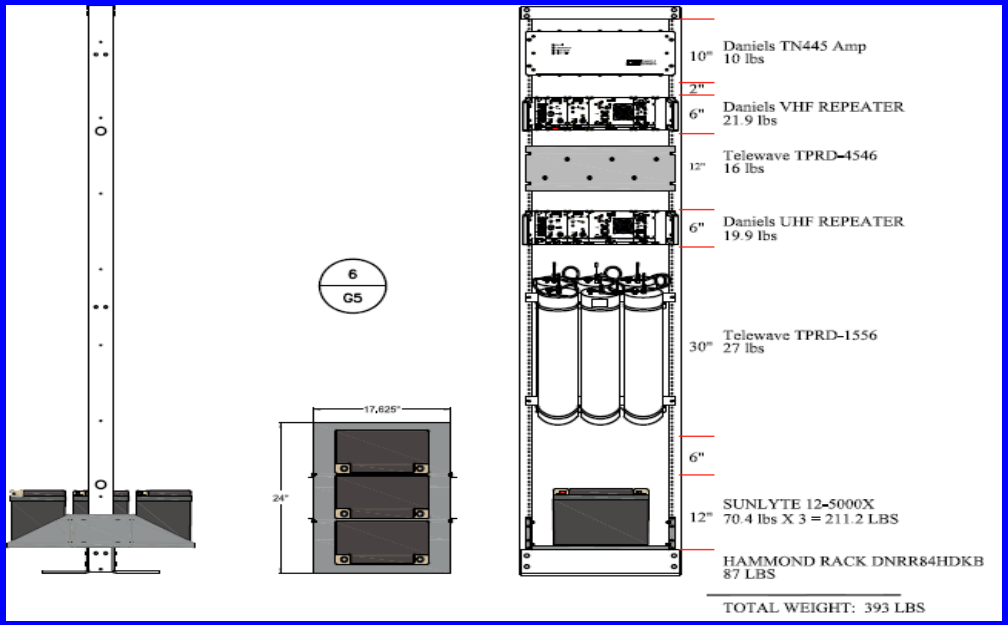
- **Designed 8-foot wide, 12-foot long shelter layout drawings**
- **Accommodates up to four equipment racks**
  - *Batteries may be stacked or mounted in an equipment rack to free up additional floor space*
  - *Standard battery backup includes one string of between two and eight, 104 Ampere/hour batteries*
  - *Extended battery backup includes two strings of between two and eight, 104 Ampere/hour batteries*



Equipment Rack with Batteries



Separate Battery String



84-inch high, 19-inch wide Equipment Rack

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Typical Drawing Files – 8-foot wide, 12-foot long Aluminum Shelter with Articulating Antenna Mast

- 8 x 12 lightweight aluminum shelter with mast typical drawing package
  - Individual drawing sheets
    - A1_8x12_Typical Shelter Layout Details
    - A2_8x12_Shelter Foundation Details Example
    - A3_8x12_Shelter Elevation Details
    - E1_8x12_Electrical Site Plans
    - E2_8x12_Shelter Panel Board Schedule
    - E3_8x12_External Grounding Plan
    - E3_8x12_Interior Grounding Plan
    - E5_8x12_Battery Typicals
    - E6_8x12_Photovoltaic One-Line Typical
    - E7_8x12_ Electrical Notes
    - G1_8x12_Grounding Typical Drawings
    - G2_8x12_Construction Typical Drawings

PDF FILES:
Click on the file to open file in Adobe

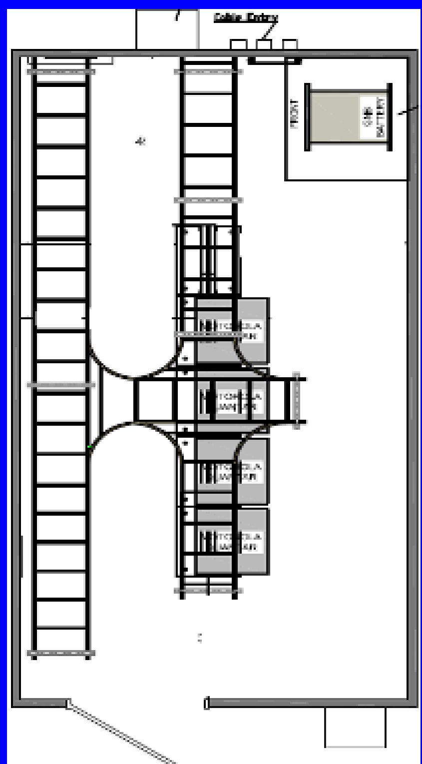
DWG Files
AutoCAD program required

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

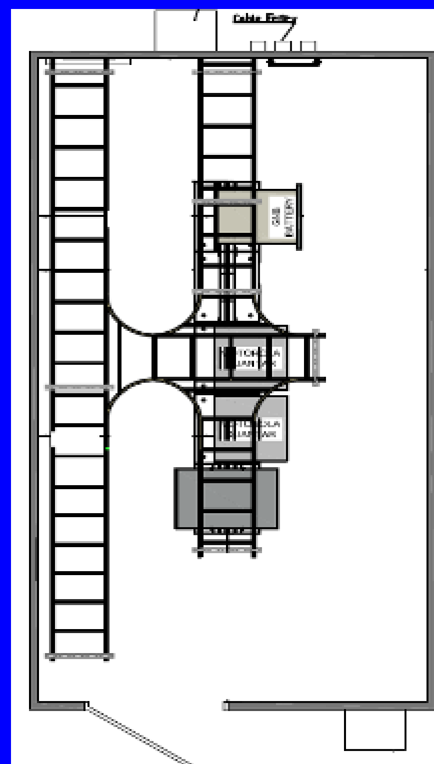
Typical 8-foot wide, 16-foot long, Aluminum Shelter with Articulating Antenna Mast

Designed 8-foot wide, 16-foot long shelter layout drawings

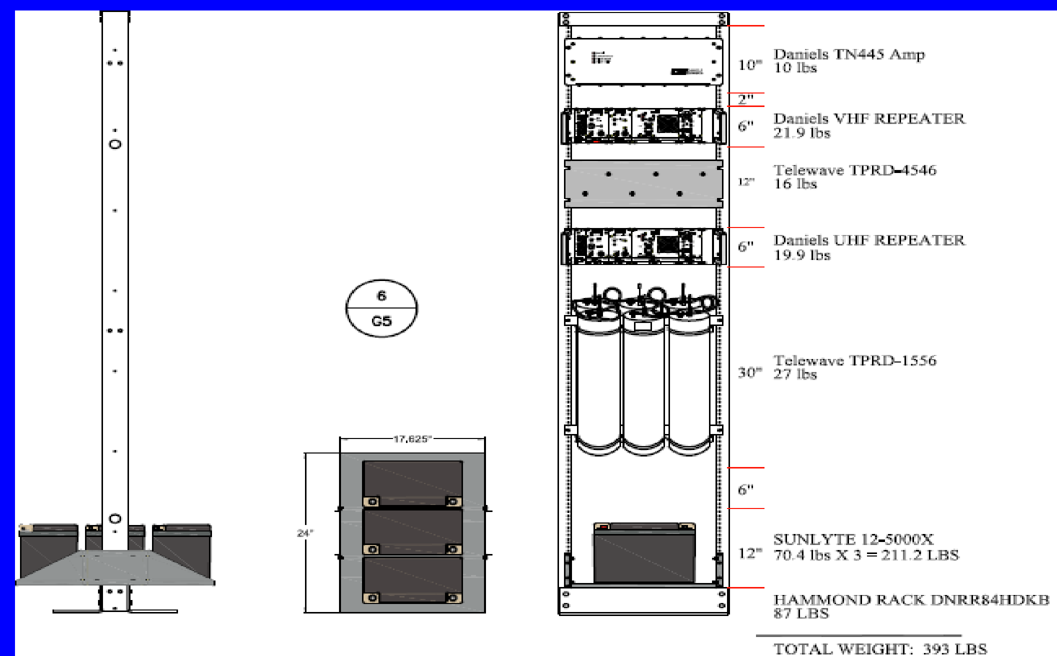
- **Accommodates up to five equipment racks**
  - *Batteries may be stacked or mounted in an equipment rack to free up additional floor space*
  - *Standard battery backup includes one string of between two and eight , 104 Ampere/hour batteries*
  - *Extended battery backup includes two strings of between two and eight , 104 Ampere/hour batteries*



Equipment Rack with Batteries



Separate Battery String



84-inch high, 19-inch wide Equipment Rack

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Typical Drawing Files – 8-foot wide, 16-foot long Aluminum Shelter with Articulating Antenna Mast

8 x 16 lightweight aluminum shelter with mast typical drawing package

- Individual drawing sheets
  - A1_8x16_Typical Shelter Layout Details
  - A2_8x16_Shelter Foundation Details Example
  - A3_8x16_Shelter Elevation Details
  - E1_8x16_Electrical Site Plans
  - E2_8x16_Shelter Panel Board Schedule
  - E3_8x16_External Grounding Plan
  - E4_8x16_Interior Grounding Plan
  - E5_8x16_Battery Typicals
  - E6_8x16_Photovoltaic One-Line Typical
  - E7_8x16_ Electrical Notes
  - F1_Tower Foundation Notes Placeholder
  - F2_Tower Foundation Drawings Placeholder
  - G1_8x16_Grounding Typical Drawings
  - G2_8x16_Construction Typical Drawings

PDF FILES:
Click on the file to open file in Adobe

DWG Files
AutoCAD program required

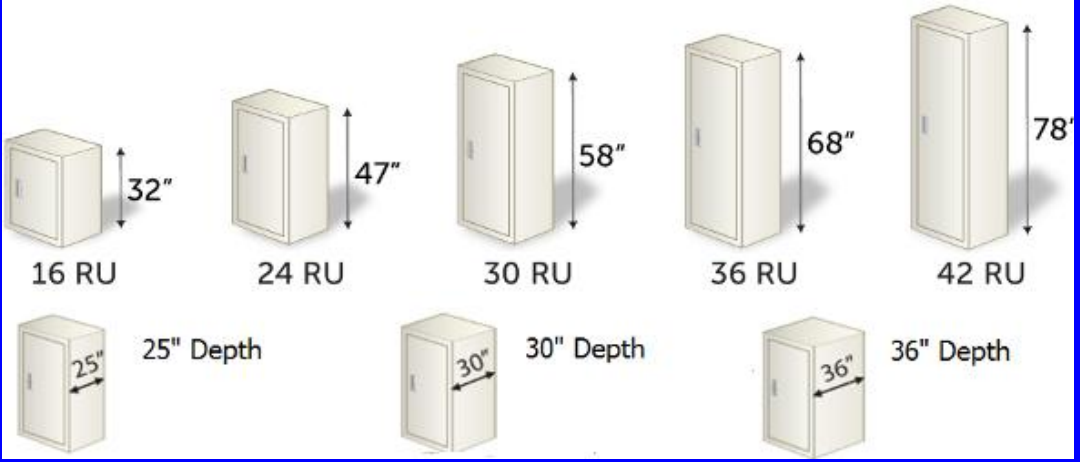
Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

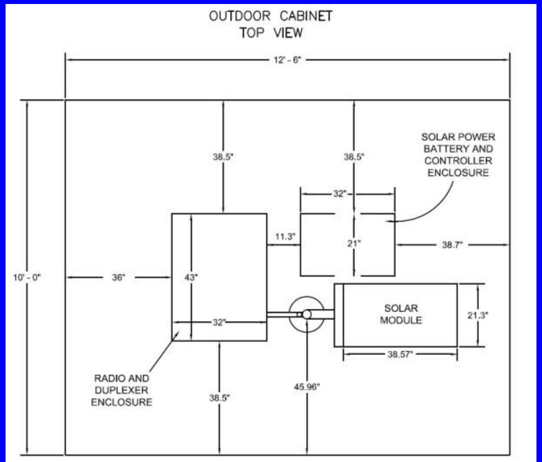
Outdoor Equipment Cabinet with 15-foot Pipe-Mast

Section 13 34 18.33 – Outdoor Equipment Cabinet

Outdoor cabinet typical design

- The equipment cabinet and battery enclosure are designed for installation on a 12-foot 6-inch long, 10-foot wide concrete pad.
- Option for installing a similar-sized steel platform can be considered.
- Option for installing a smaller concrete foundation or platform with a 36-inch wide developed work area with aggregate around the foundation can be considered.
- A 20-foot high, 4-inch diameter pipe mast is installed next to the equipment cabinet embedded in a 5-foot deep, 18-inch diameter concrete foundation.
- The antenna is designed to be mounted at the top of the pipe mast.
- The solar panel is designed to be mounted on the pipe mast below the antenna.
- The RF cable from the antenna is designed to be routed in conduit to the equipment cabinet.
- DC-power wiring is designed to be routed in conduit from the solar panel array into the battery enclosure.
- The equipment cabinet has various size options to accommodate one or more radio systems.





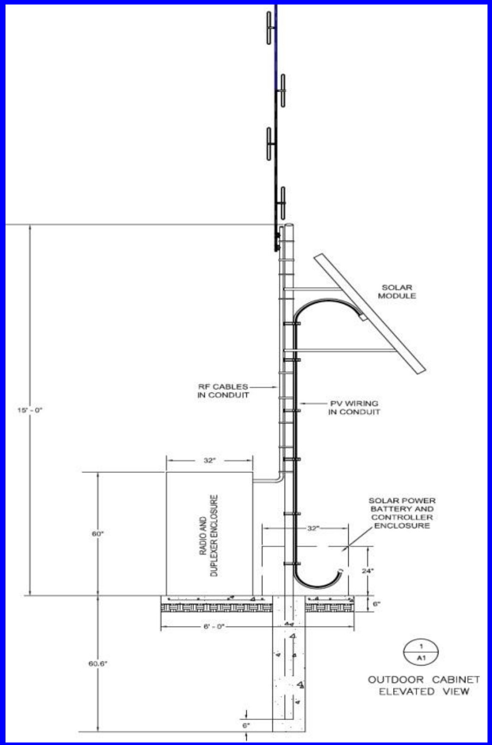


Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

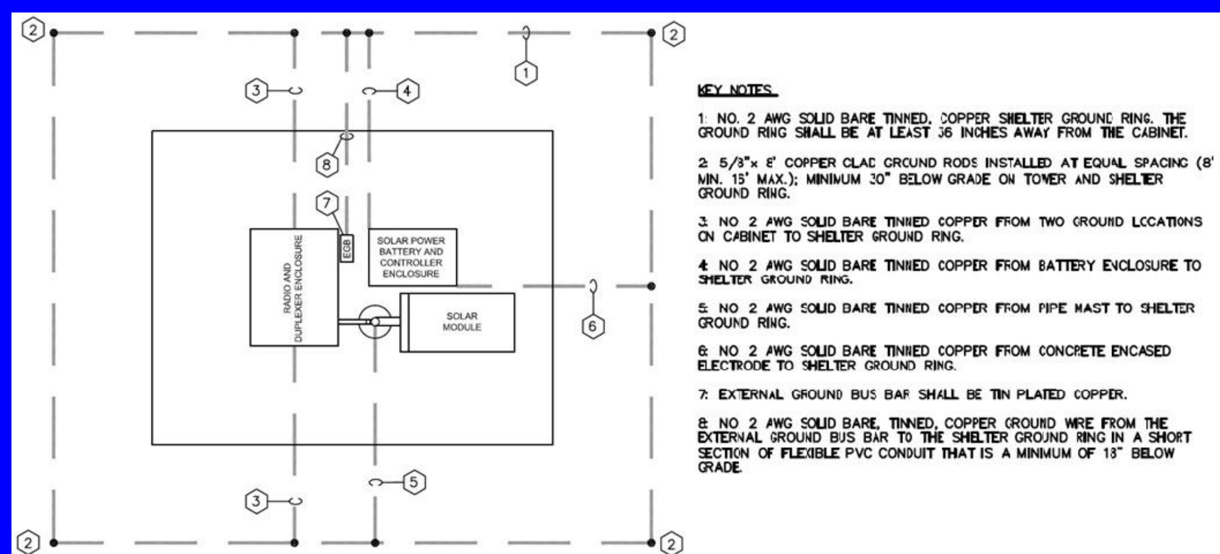
Outdoor Equipment Cabinet – Grounding Requirements

Motorola R56 Section 4.7.8 – Outdoor Cabinet Grounding (Earthing)

Section 33 79 15.13 – Outdoor Cabinet Grounding

The outdoor equipment cabinet must be encircled with a ground ring.

- The ground ring must be installed at least 24 inches from the cabinet foundation/pad;
- The cabinet ground ring must have a ground rod installed at each corner with equal distance between rods from 8 to 15 feet;
- Ground rods must have a minimum separation from other ground rods equal to their length (ANSI T1.313-2003);
- The cabinet ground ring must bond to the tower ground ring, if equipped;
- Metallic objects near the cabinet must be bonded to the cabinet grounding electrode system as detailed in Motorola R56 Section 4.7.10 - Metallic Objects Requiring Bonding;
- The cabinet grounding electrode system must bond to the cabinet's internal ground point and cabinet housing using a #2 AWG or coarser, tinned, copper conductor; and
- Cabinets installed on pads that incorporate a footing must be equipped with a concrete-encased electrode, in addition to the ground ring.



Fiberglass Shelter With Antenna Radome – Design

Section 13 34 18.23 – Fiberglass Shelter With Antenna Radome

Fiberglass shelter typical design drawings:

- The fiberglass shelter is 6 feet 3 inches long, 6 feet 3 inches wide and 12 feet high;
- The upper portion of the shelter is equipped with a 5-foot 9-inch fiberglass radome with a PVC pipe mast for mounting antennas inside the shelter;
- The shelter is designed with metal skids to allow installation directly on the ground without the need for a concrete foundation;
- The shelter typically has solar panels mounted on the exterior walls;
- The shelter is designed to be anchored to the ground using guy wires attached to duckbill earth anchors;
- Guy wires used in Alaska are nonmetallic, Kevlar to eliminate the requirement for additional grounding; and
- The shelter is designed with shelves capable of housing two 19-inch wide, 36-inch high equipment racks and up to 40 batteries.

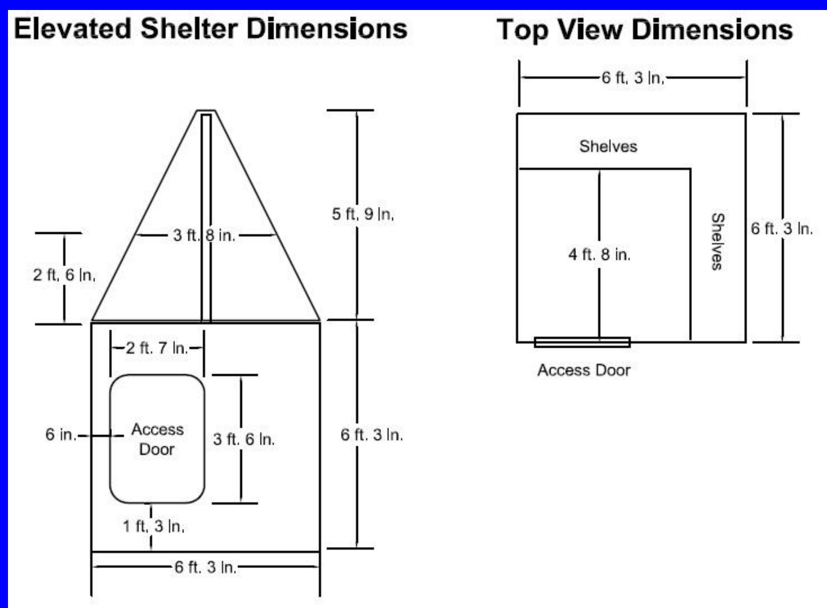
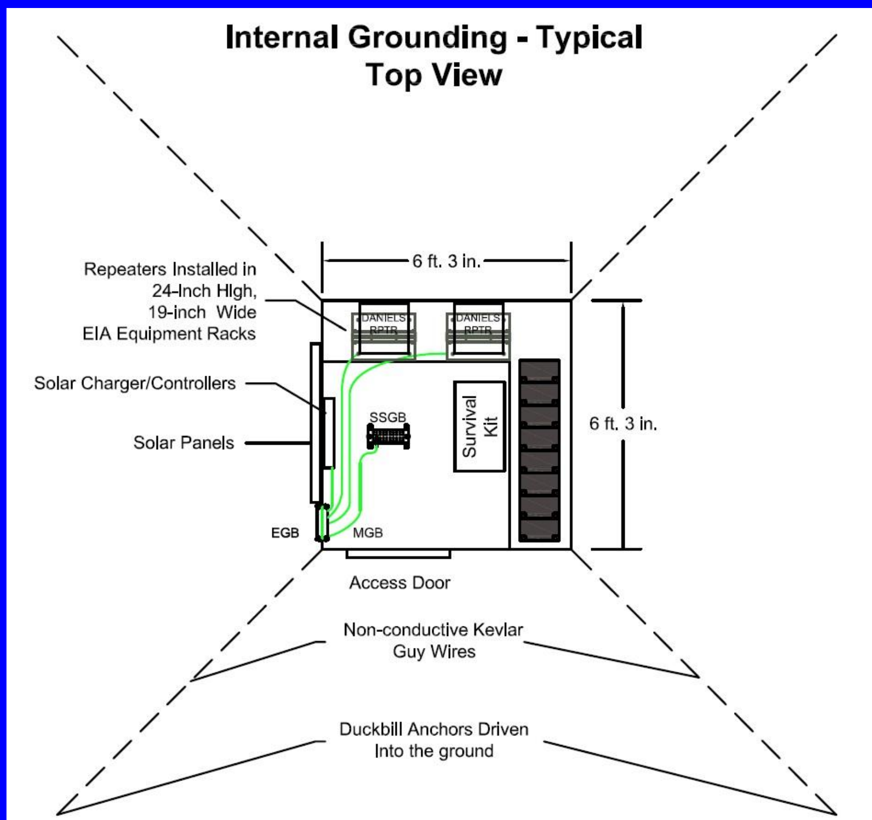


Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Fiberglass Shelter With Antenna Radome – Grounding Design

Fiberglass shelter typical grounding design

- The shelter is equipped with a #2 AWG, tinned copper ground ring with four equally spaced ground rods. A 24-inch grounding plate is designed to provide supplemental grounding at facilities with poor or shallow soils;
- The ground ring is installed 36 inches from the shelter;
- The concrete foundation is equipped with a concrete-encased electrode bonded to the ground ring;
- The shelter is equipped with an internal master ground bus bar and an external ground bus bar bonded to the ground ring; and
- The shelter is equipped with a subsystem ground bus bar to provide a grounding location for RF surge-protection devices.



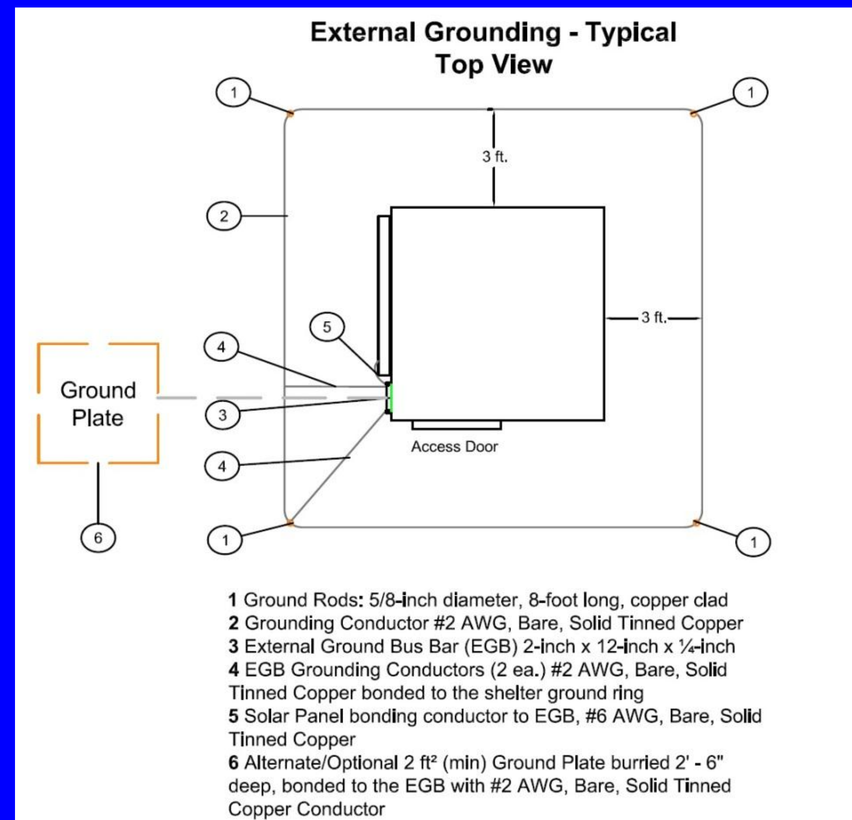


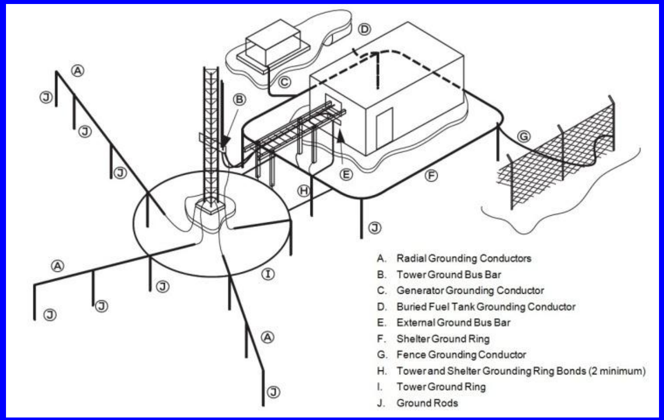
Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

External Grounding System Requirements

Motorola R56 Standard (Chapter 4)

The minimum external grounding system must consist of the following components:

- Shelter ground ring with each corner of the shelter support frame grounded
- Tower ground ring with each tower leg grounded
- Radial grounding conductors extending out from the tower and/or shelter ground ring
- Ground rods or other grounding electrodes
  - Minimum ground rod length is 8 feet
- Grounding conductors
  - Minimum grounding conductor size and type is #2 AWG, tinned, solid, copper
- Tower ground bus bar
  - Tinned copper bus bar with a minimum dimension of 12-inch wide, 4-inch high, ¼-inch thick
- External ground bus bar
  - Tinned copper bus bar with a minimum dimension of 12-inch wide, 4-inch high, ¼-inch thick.
- Metallic ancillary device grounding conductors
  - Minimum above grade grounding conductor size and type is #6 AWG, bare, tinned, solid, copper up to 6 feet; and
  - #2 AWG for longer lengths or where routed below grade.



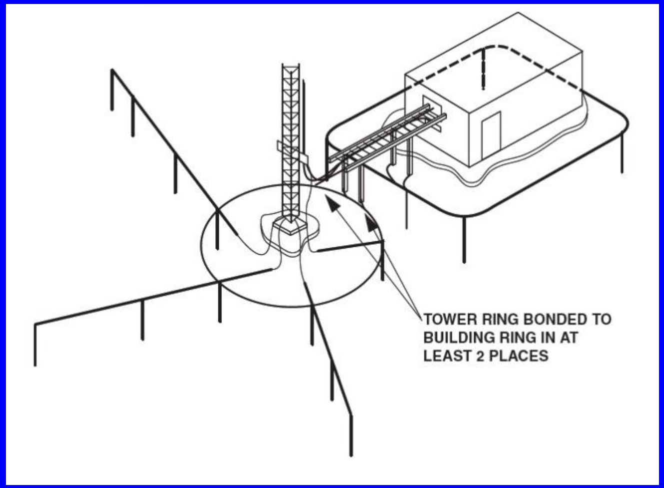


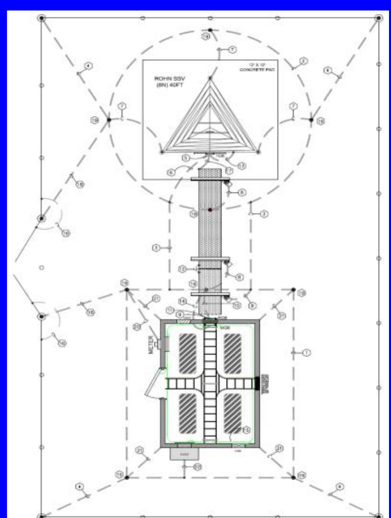
Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

External Ground Ring – Installation Requirements

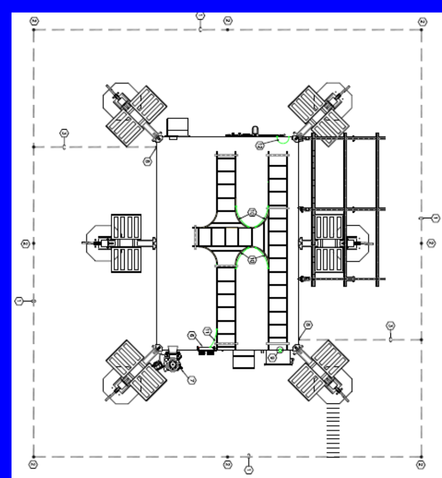
Motorola R56, Section 4.4.1.6 – External Building and Tower Ground Ring

External ground rings must meet the following installation criteria:

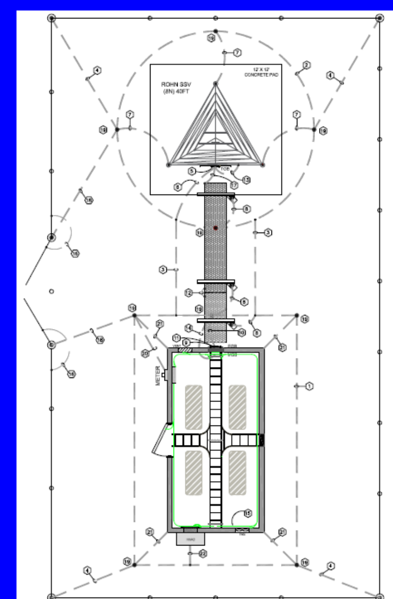
- The shelter ground ring must encircle the shelter at least 36 inches from the shelter base and or concrete foundation.
- The tower ground ring must encircle the tower structure at least 24 inches from the foundation.
  - The shelter ground ring and tower ground ring must be bonded together in at least two points;
  - Grounding conductors must be #2 AWG or coarser, bare, solid, tinned, copper conductors;
  - Ground rings are required be in direct contact with the soil at a depth of 30 inches; and
  - Ground rods must have a minimum separation from other ground rods equal to its length (ANSI T1.313-2003).
- Shelters foundations incorporating a footing must be equipped with a concrete encased electrodes, in addition to the ground ring.



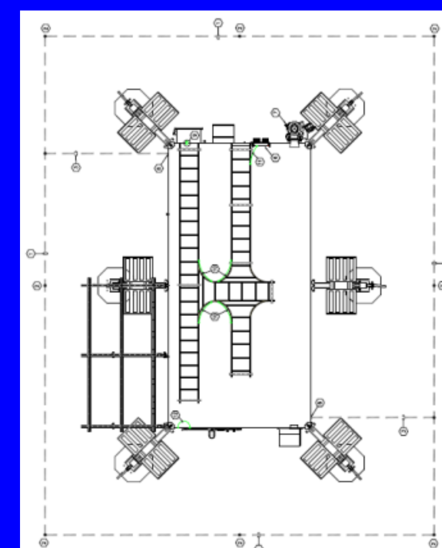
8 x 12 Prefabricated Shelter with Tower



8 x 12 Aluminum Shelter with Articulating Mast



8 x 16 Prefabricated Shelter with Tower



8 x 16 Aluminum Shelter with Articulating Mast

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Grounding Metallic Ancillary Devices

Motorola R56, Section 4.7.10 – Metallic Objects Requiring Bonding

Section 33 79 20 - Bonding Metallic Ancillary Devices to External Grounding System

The objective of bonding metallic objects to ground is to equalize the potential between conductive parts for personnel safety and to prevent arcing between metallic components that could otherwise be at different electrical potentials. Bonding prevents nonlinear refracting of radio frequency signals that can cause interference. The grounding conductors must be as short and straight as possible and routed in a downward manner towards the soil's surface.

- All metallic ancillary devices located within 6 feet of the external grounding electrode system, or within 6 feet of a grounded metallic item must be electrically bonded to the external grounding electrode system.
  - In high lightning-prone geographical areas, or areas of high soil resistivity, bonding all metallic objects that are located within 10 feet of the external grounding electrode system, or within 10 feet of a grounded metallic item is recommended.
- Items that must be grounded include, but are not limited to, the following:
  - Ice bridges
  - Metallic entry ports and panels
  - HVAC units
  - Vent covers
  - Metallic support frames and skid plates
  - Metal roofing panels
  - Fences
  - Solar panels
  - Electrical meter panels
  - Service disconnect panels
  - Storage tanks
  - Generators
  - Telephone company cable shields
- The series or daisy-chain method, which refers to any method of connecting conductors from one ancillary device to a second and possibly on to a third device, is prohibited.

Tower Ground Bus Bar

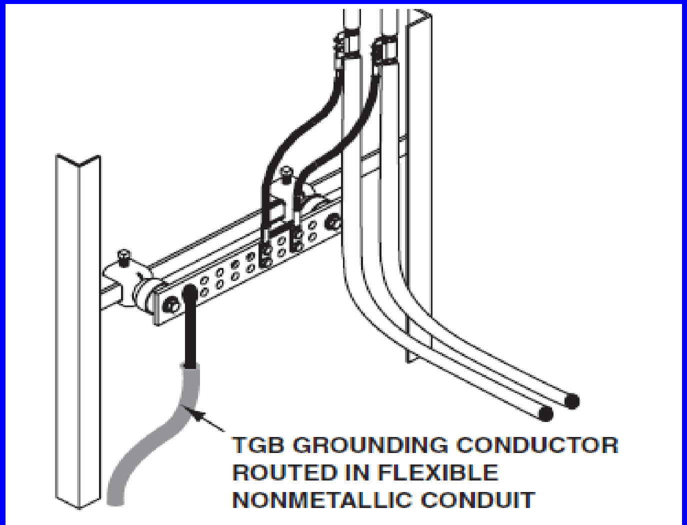
Motorola R56, Section 4.4.3.1 – Tower Ground Bus Bar

Section 33 79 86 – Ground Bus Bars

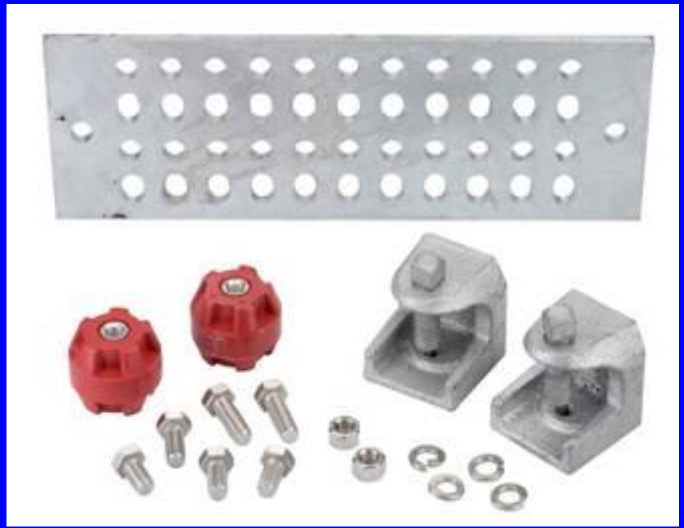
The BLM RI CASHE Program requires installing a tower ground bus bar (TGB) at the base of every tower to provide a convenient, maintainable grounding location for each RF cable ground kit.

The TGB must be installed below the RF cable ground kits where the RF cables transition horizontally toward the shelter.

- The minimum size bus bar must be a 4-inch wide, 12-inch long, ¼-inch thick, tinned, copper bus bar with predrilled holes that provide for using standard-sized two-hole lugs;
- TGB must be tin-plated copper to impede corrosion and deter theft;
- TGB must be grounded directly to the tower ground ring with two #2 AWG, solid, tinned-copper grounding conductors routed in flexible nonmetallic conduit;
- All bonding connections to the TGB and tower ground ring must be made using exothermic welds (preferred) or irreversible, high-compression crimp connectors; and
- RF cable ground kits may be bonded using single or two-hole connectors provided by the manufacturer.



Typical Tinned TGB Installation



Typical Tinned Ground Bus Bar Kit

TGB Location

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

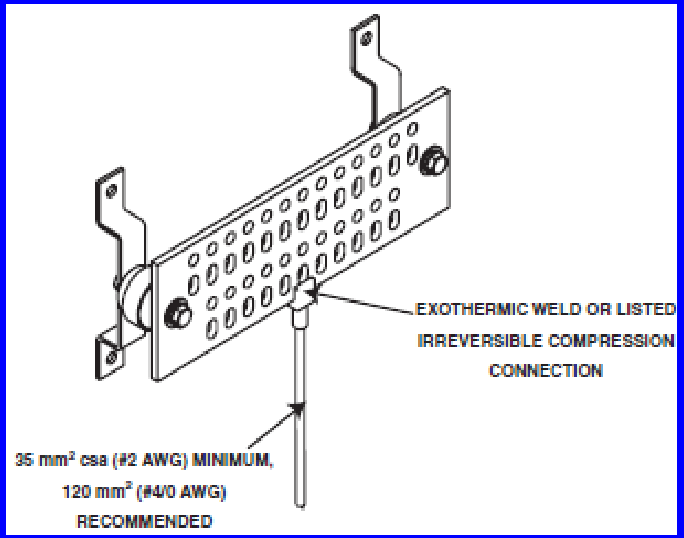
External Ground Bus Bar

Motorola R56, Section 4.4.3 – External Ground Bus Bar

Section 33 79 86 – Ground Bus Bars

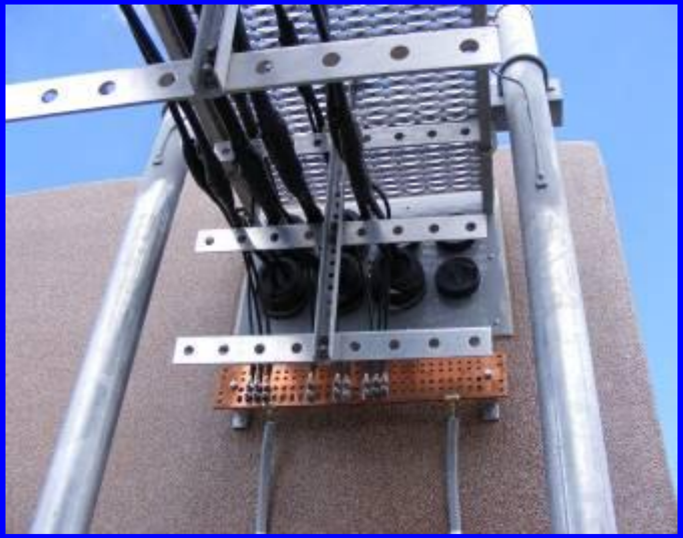
The purpose of the external ground bus bar (EGB) is to provide a convenient grounding termination point for RF cable (transmission line) ground kits and other cables prior to entering the communications shelter.

- The EGB must be installed within 24 inches below the RF cable entrance to the shelter.
  - The minimum sized bus bar must be a 4-inch wide, 12-inch long, ¼-inch thick, tinned, copper bus bar with predrilled holes that provide for the use of standard-sized two-hole lugs;
  - The EGB must be tin-plated copper to impede corrosion and deter theft;
  - The EGB must be grounded directly to the shelter ground ring with a minimum of two, #2 AWG, solid, tinned-copper grounding conductors; and
  - All bonding connections to the EGB and shelter ground ring must be made using exothermic welds (preferred) or irreversible, high-compression crimp connectors.
- An integrated copper entry panel can be used as the EGB.



Typical EGB Installation

Typical Tinned Ground Bus Bar Kit



Typical EGB Location

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Internal Shelter Grounding System

Motorola R56, Section 5.2 – Common Grounding

Section 33 79 84.13 – Bonding Equipment to Internal Grounding System

Proper bonding and grounding is essential. Inadequate or improper equipment bonding and grounding can allow a difference in ground potential to exist between system components that may result in injury to personnel, system failure, and equipment damage. Ground fault, lightning, ground-potential rise, electrical surges, and power-quality anomalies cannot be prevented.

A properly installed grounding system minimizes the damage caused by these events. An internal grounding system must have low-electrical impedance and conductors large enough to withstand high-fault currents. The lower the grounding system impedance, the more effectively the system can dissipate energy to the soil.

- A single-point grounding system must be established inside the communications shelter.
- The single-point ground is established by the master ground bus bar (MGB).
  - The MGB is bonded to the external grounding system established by the shelter ground ring, tower ground ring, and electrical power system ground.
- The internal perimeter ground bus (IPGB) is an extension of the single-point ground for bonding ancillary metallic objects.
  - The IPGB consists of two, independent, #2 AWG or coarser, stranded, copper, green-jacketed conductors routed in opposite directions around the interior of the shelter from the MGB; and
  - The two IPGB conductors must be separated by a minimum 4-inch gap, opposite of the MGB. The 4-inch gap prevents the formation of a ground loop.
- Ancillary metallic objects are required to be bonded to the IPGB or MGB with #6 AWG or coarser, stranded, copper, green-jacketed, conductors using listed (UL 467 or equivalent) connectors.
- Each electronic communications device, radio, and duplexer must be bonded to a rack ground bus bar (RGB) or directly to the MGB with #6 AWG or coarser, stranded, copper, green-jacketed, conductors using listed (UL 467 or equivalent) connectors.
  - Each RGB must be bonded directly to the MGB using a #2 AWG or coarser, stranded, copper, green-jacketed, conductor using listed (UL 467 or equivalent) two-hole connectors or exothermic welds; and
  - Electronic communications devices and radio equipment must not be bonded to the IPGB.

Internal Grounding System – Typical Design Drawing

Motorola R56, Section 5.2 – Common Grounding

Section 33 79 85 – Internal Perimeter Ground Bus

The drawing below shows a typical internal grounding system design for an 8-foot wide, 12-foot long, prefabricated communications shelter. To view the full-size internal grounding design drawing, click the image below. The typical internal grounding system design consists of the following:

- Master ground bus bar (MGB) installed within 24 inches below the RF cable entrance panel
- Internal perimeter ground bus (IPGB) encircling the perimeter of the shelter, 6 inches below the ceiling, or 7 feet above the floor
- Rack Ground Bus Bars installed in each equipment cabinet or equipment rack and bonded to the master ground bus bar

- Bonding jumpers are installed between each metallic ancillary device and the IPGB or MGB, including the following devices:
  - Electrical panel boards
  - Cable ladders/runways
  - HVAC vent covers
  - Intake vent cover
  - Exhaust fan chassis
  - The metal door and doorframe
  - The RF cable entrance panel
  - Telecommunication equipment

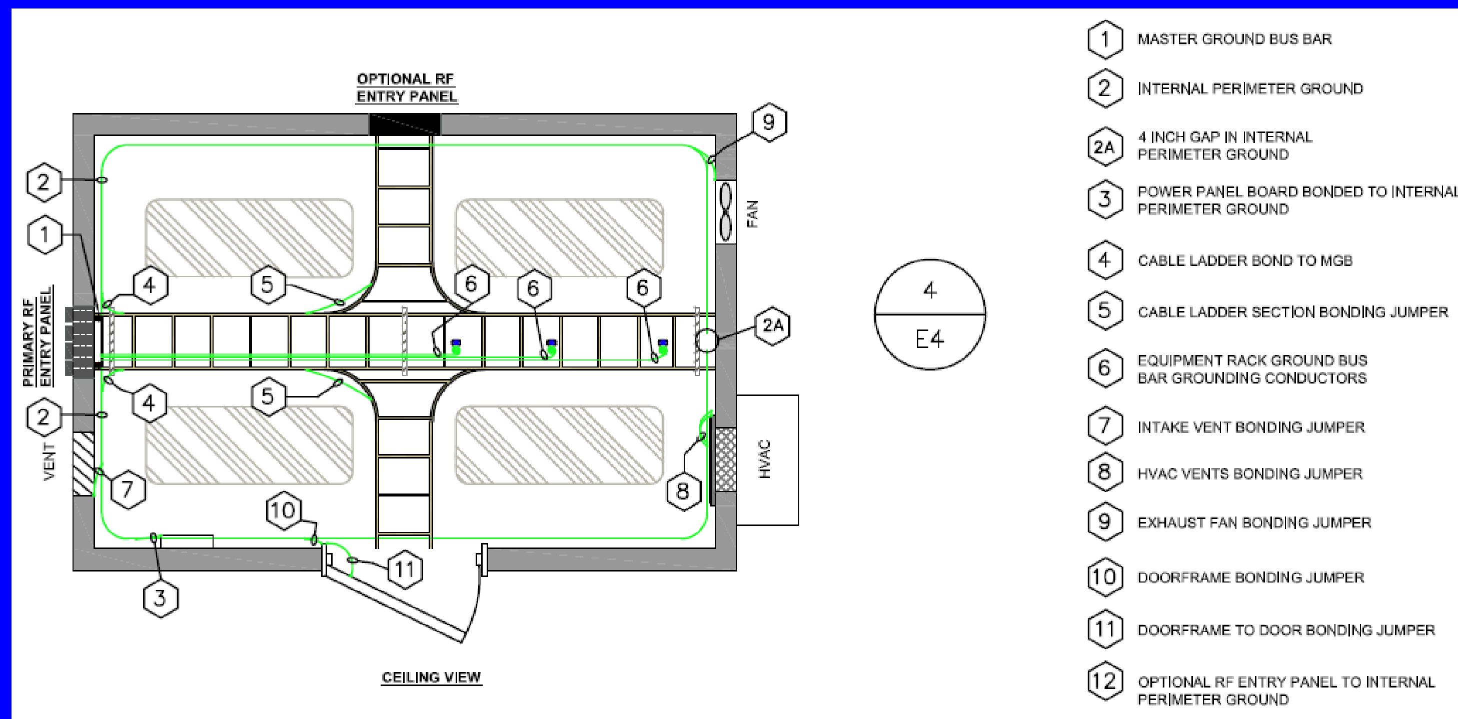


Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

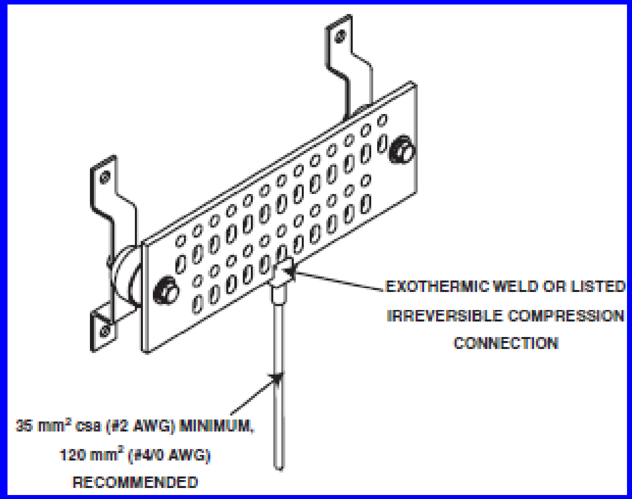
Master Ground Bus Bar

Motorola R56, Section 5.3.1 - Master Ground (Earth) Bus Bar

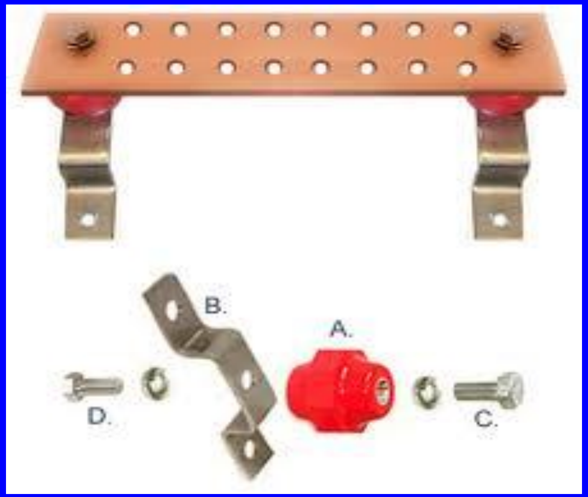
Section 33 79 86 – Ground Bus Bars

The purpose of the master ground bus bar (MGB) is to provide a convenient internal grounding termination point for the communication system and to serve as a dedicated extension of the common grounding electrode system. A typical MGB with insulated mounting hardware is shown in Motorola R56 Figure 5-6. The MGB functions as the primary internal grounding location for all equipment ground bus conductors, grounding conductors, and communications equipment in the shelter.

- The MGB must be a 4-inch wide, 12-inch long, ¼-inch thick, copper bus bar with predrilled holes that provide for using standard-sized two-hole lugs. It is recommended that the bus bar be electro-tin-plated to reduce contact resistance.
- The MGB must be sized in accordance with the immediate application and consideration should be given to future growth at the radio facility.
- The MGB must be listed by a nationally recognized testing laboratory in accordance with ANSI-J-STD-607-A-2002.
- Whenever practical, the MGB should be located within 24 inches of the RF cable entrance into the equipment shelter or cabinet, preferably on the same wall or at the same entry location as the electrical service and the telecommunications cables. This configuration allows for a single-point ground window to be established for the internal grounding system.



Typical MGB Installation



Typical Ground Bus Bar Kit

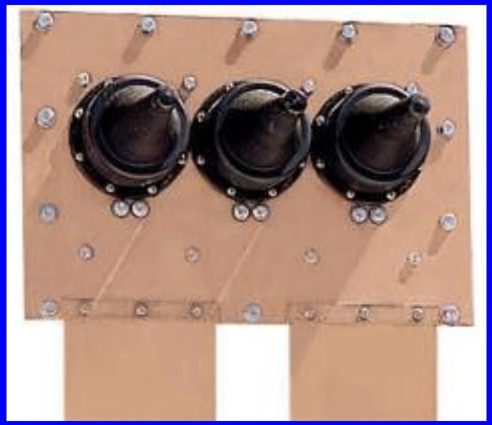
Location of MGB

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Copper-integrated Entry Panel

Motorola R56, Section 5.3.1 - Master Ground (Earth) Bus Bar

- Copper-integrated entry panels are referred to by several names, such as copper coaxial entry panel, port earthed entry panel, Polyphaser ™ earthed entry panel, or by the acronym PEEP ™.
  - A single, properly installed, integrated cable entry port constructed of solid copper that is electrically continuous between the interior and exterior of the structure can be used as the master ground bus bar, external ground bus, and cable entry panel.
  - The copper-integrated entry panel must have adequate surface area for proper termination of the internal grounding conductors.
  - The copper-integrated entry panel must have adequate ports to facilitate entry of planned and future RF cables (typically eight ports).
- Weather-sealing boots must be installed for each entry port.
- The copper-integrated entry panel is typically supplied with two copper grounding straps that facilitate grounding the entry panel to the shelter ground ring.
  - Bonding these straps to the #2 AWG shelter ground ring conductor is best accomplished by sandwiching the copper strap between two 6-inch copper bus bars that are exothermically welded to the shelter ground ring.
- An alternative grounding method is to bond the exterior of the copper entry panel to the shelter ground ring with two independent grounding conductors.
  - The conductors bonding the copper-integrated entry panel to the shelter ground ring must be a minimum size of #2 AWG and fastened to the copper-integrated entry panel using exothermic welds, irreversible compression-type connectors, or UL 467-listed, compression two-hole, long-barrel lugs. The conductor must not be smaller than the largest conductor installed within the internal grounding system.
  - The grounding conductors must be bonded to the shelter ground ring using exothermic welds or UL 467-listed, irreversible, high-compression crimp connectors.



Typical copper-integrated Entry Panel Exterior View

Typical copper-integrated Entry Panel Exterior View

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Bonding Ancillary Equipment to the Internal Grounding System

Motorola R56, Section 5.5.1 – Equipment and Ancillary Support Apparatus Bonding

Section 33 79 84.13 – Bonding Equipment to Internal Grounding System

- All ancillary support apparatus must be bonded to the master ground bus bar, subsystem ground bus bar, or internal perimeter ground bus with an individual bonding or grounding conductor.
  - For lengths up to 13 feet, grounding conductors must be #6 AWG or coarser, green-jacketed, stranded copper
  - For lengths between 13 feet and 33 feet, #2 AWG or coarser conductors must be used
- Items required to be bonded include but are not limited to:
  - Electrical power panels
  - Junction boxes
  - Metal doors
  - Cable runways/ladders
  - Metal walls
  - Battery rack chassis
  - Vent covers
  - Exhaust fan chassis

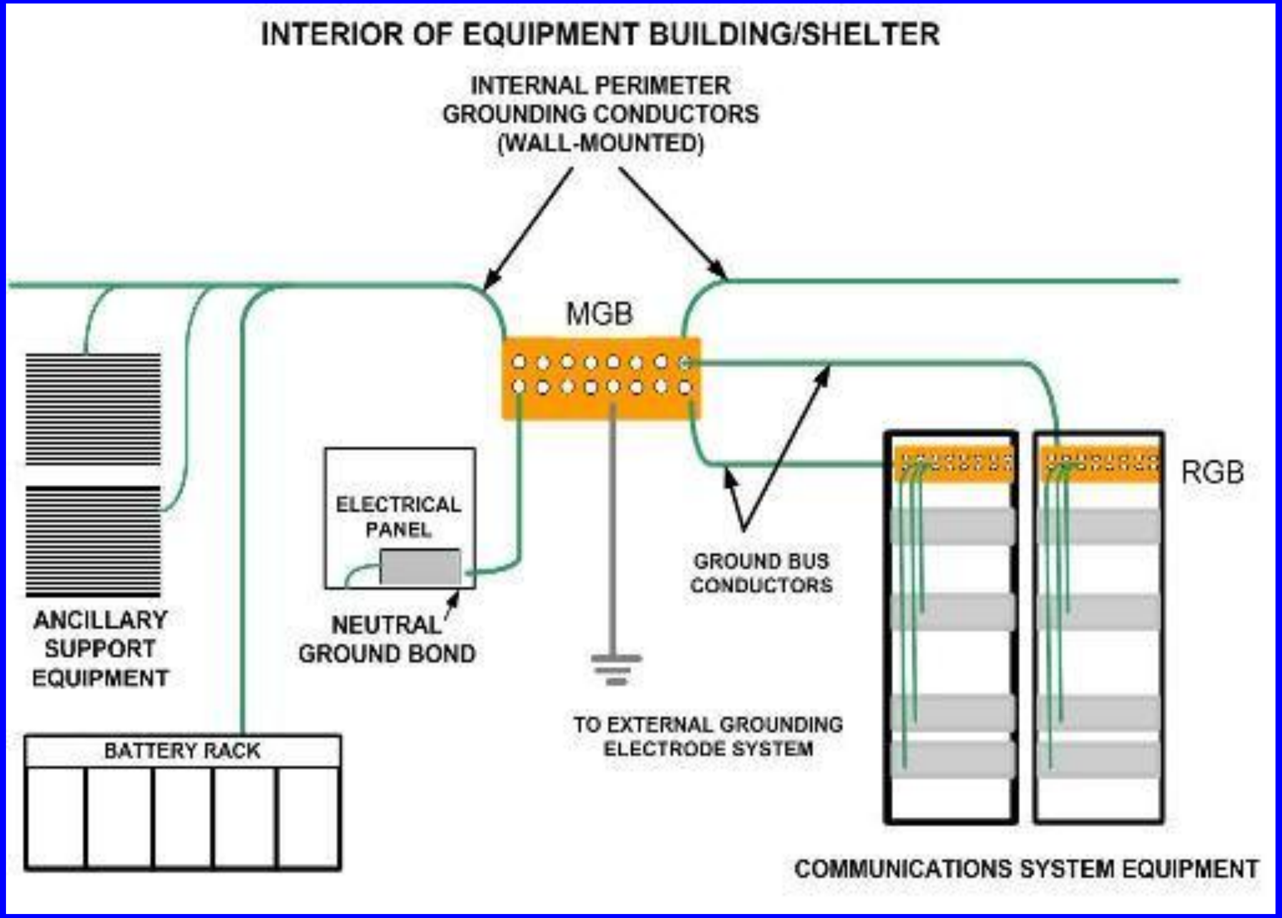
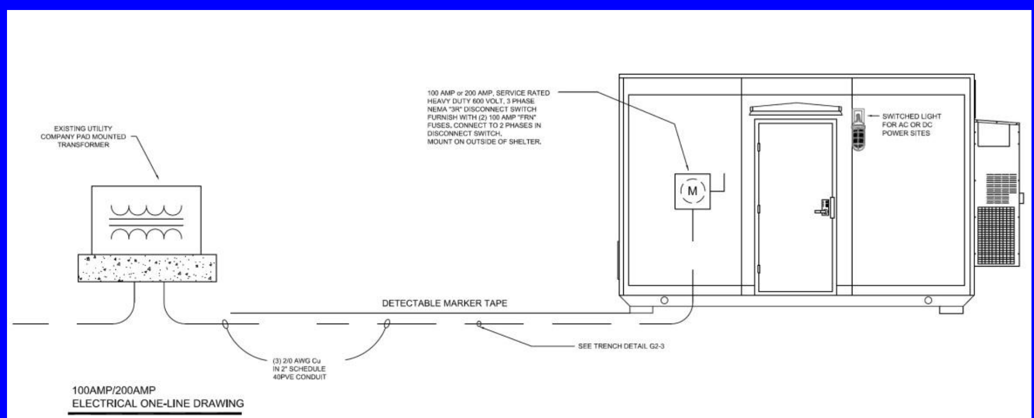


Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

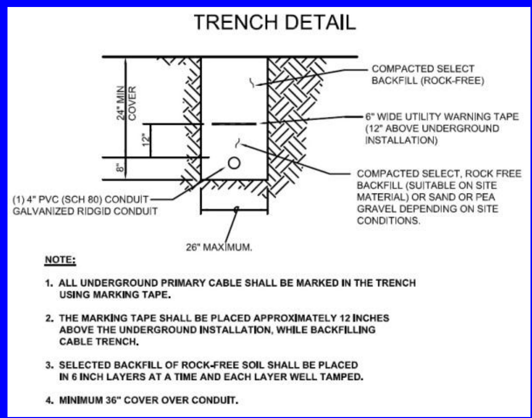
Commercial Electrical Power – Service

Motorola R56 Standard 6.2.1 – Electrical Service

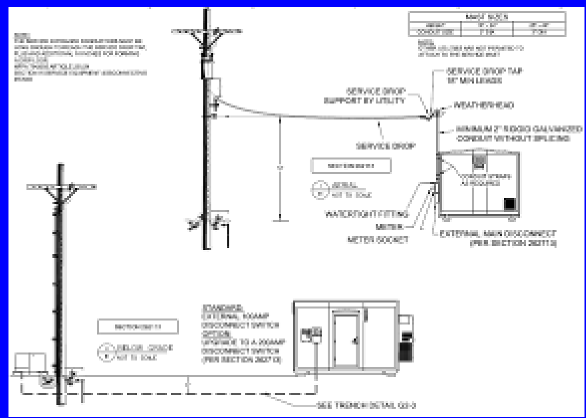
- **Commercial Electrical Power Service Requirements**
  - The Motorola R56 Standard requires that the minimum acceptable service for US installations is 100 Amperes at 120/240 volts of alternating current.
  - A 200-Ampere or larger service may be required for existing and future loads, or for additional circuit breaker positions.
  - The continuous electrical load must not exceed 80% of the electrical system (i.e., wire, panel board, breakers, and service rating). Using this standard ensures that the power capacity supplied to the communications site is adequate.
  - Alternating current power systems must be designed, installed, and maintained in accordance with jurisdictional standards and regulations.
- **Electrical Service Installation**
  - The power company usually provides the service to the meter in underground installations and to the weatherhead in overhead installations.
  - The wiring after the meter is typically the responsibility of the customer.
  - Installing commercial-service wiring in below grade conduit increases safety at the radio facility by eliminating shock hazards for tower climbers and service vehicles.



Click to view Typical Below Grade Electrical Service Installation



Click to view Typical Trench Detail



Click to view Typical Electrical Service Installation

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Commercial Electrical Power – Service-Disconnect

Motorola R56 Standard 6.2.1 – Electrical Service

Main Electrical Power Service-Disconnect Panel

- The Motorola R56 Standard requires that a main electrical service-disconnect, fused disconnect, or both be installed before all other panels and equipment, including a generator transfer switch.
- NEC 230.70 – Service Equipment Disconnecting Means states that a means must be provided to disconnect all conductors in a building or structure from the service-entrance conductors.
- The main electrical service-disconnect can be located inside the shelter, on the outside of the shelter, on the utility pole, or on an H-frame within the radio facility compound. The following installation criteria must be met:
  - The service-disconnect panel must be installed in a readily accessible location either outside the shelter or inside the shelter nearest the point of entrance of the service conductors.
  - The service-disconnect panel must be permanently marked to identify it as a service disconnect.
  - For a stand-alone shelter, the main disconnect should be located on the same wall as the RF cable entry port, the telephone entry point, and the master ground bus bar; and
  - If it is not possible to locate these components on the same wall, they must be located on an adjacent wall as close together as possible.
- The electrical service-disconnect must be grounded to the shelter ground ring using a #2 AWG or coarser, bare, solid, tinned-copper grounding conductor.

The neutral-to-ground bond must be established in the service-disconnect panel or interior distribution panel board.

- The neutral-to-ground bond must be established in the interior main distribution panel board when the service-disconnect is mounted remotely and not on the shelter exterior.

Shelter-mounted Meter and Service-Disconnect Panel

Service-Disconnect Panel Mounted on Utility Pole

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Commercial Power – Surge-Protection

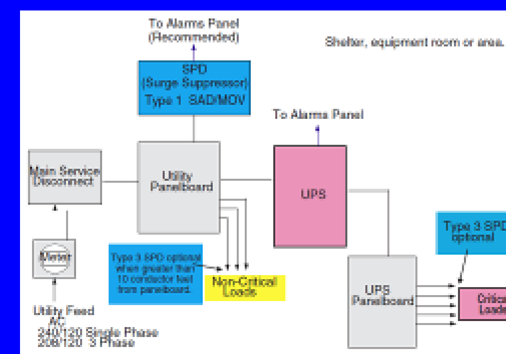
Motorola R56 Section 7.4.2 – Surge Protection Device Types

Primary Surge-Protection Devices

Installation of surge-protection devices (SPDs) is a requirement for all communication facilities and is essential for all facilities where communication-related electronics and electrical equipment is used. Surges and transient power anomalies are potentially destructive electrical disturbances, the most damaging being overvoltage occurrences and short-duration overvoltage events. Sometimes referred to as "spikes," high-energy transient power anomalies can arise from inductive load switching, other events in the power system, or capacitive and inductive coupling from environmental events such as nearby lightning activity.

- SPDs must comply with UL 1449 - Standard for Safety for Surge-Protective Devices, 3rd Edition.
  - UL 1449, 3rd Edition applies to devices used to repeatedly limit transient voltages on 50/60 Hertz circuits, 1,000 Volts and less.
- Four classifications or types of SPDs have been established, depending on where in the electrical system the device is connected. The four Types detailed below must be included in design considerations for SPD installations within the shelter.
  - SPD Type 1: Permanently connected SPDs installed on the line/supply side just after the meter
  - SPD Type 2: Permanently connected SPD installed on the load side of the service panel
  - SPD Type 3: Point of use SPDs, installed at a minimum conductor length of 30 feet from the electrical service panel to the point of use
  - SPD Type 4: Individual component devices installed by the equipment manufacturer
- When determining what type of SPD to use, the *location* and *application* are the determining factors. In addition, peak surge-current, voltage or frequency responsive circuitry requirements, operating voltage, wiring, and enclosure type are also required for proper selection.

Typical Type 1 SPD



Typical Type 1 SPD Installation Drawing

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Commercial Electrical Power – Panel Boards

Section 26 24 16 – Panel Boards

Commercial Electrical Power Panel Board Requirements

Panel boards must be installed in accordance with NFPA 70 384, the manufacturer's instructions, and applicable NECA installation requirements.

- A minimum 36-inch work space must be provided in front of any electrical panel board in accordance with NFPA 70 110.26.
- A minimum work space equal to the width of the panel board or 30 inches, whichever is greater, must be provided in accordance with NFPA 70 110.26.
- Each panel board must be equipped with a main circuit breaker.
- Panel boards must be installed plumb and the top of the enclosure must not be more than 6 feet above the finished floor.
- Provide and install a plastic engraved nameplate for each panel board detailing the following:
  - Panel designation
  - Panel operating voltage
  - Source and circuit number of panel board supply (for disconnection and isolation)
- Each panel board must have a neatly typed circuit directory installed, clearly identifying the loads served by each branch circuit breaker.
- All unused circuit breaker spaces must have filler plates installed.
- Each panel board chassis must be bonded to the internal grounding system.

Typical 100-Ampere Panel Board with Main Breaker

Typical 200-Ampere Panel Board with Main Breaker

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Commercial Electrical Power – Distribution

- **Electrical Distribution**
  - The shelter manufacturer must furnish and install conduit, conductors, boxes, etc. as required for a complete electrical assembly.
  - All electrical wiring and circuiting must be installed in EMT conduit.
  - Fittings and connectors must be steel compression type with insulated throats (die-cast fittings are not acceptable).
  - Conduit must be supported in 4-foot increments, using steel straps.
  - Conduit bends must be made with a manufactured mechanical bender or factory-made elbows must be used.
  - All conduit must be routed exposed and attached to the inside wall of the shelter.
  - All wire must be copper, with thermoplastic heat and water-resistant nylon-coated insulation (aluminum conductors are not acceptable).
  - The minimum wire size is #12 AWG.
  - All wire runs must be continuous (splices are not allowed).
  - An equipment grounding conductor must be installed in every conduit for every circuit run.
  - Metallic conduit must not be solely relied upon for grounding.
  - Equipment grounding conductors must be sized per NEC requirements.
- **Simplex Receptacles**
  - The shelter manufacturer must furnish and install simplex receptacles mounted on the ceiling above each equipment rack space.
  - Each receptacle must be 20-Ampere, NEMA 5-20R T-Slot (Hubble HBL5361 or equivalent) specification grade.
  - Each receptacle must be on an individual 20-Ampere, dedicated circuit (only one receptacle on each circuit).
- **Duplex Receptacles**
  - Provide duplex/double receptacles every 4 feet inside the shelter along each wall.
  - All receptacles must be 15-Ampere, NEMA 5-15R specification grade.
  - Each receptacle must be on an individual 15-Ampere, dedicated circuit (only one receptacle on each circuit).

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Battery Backup Systems

Section 26 33 00 – Battery Systems

During a commercial power interruption, backup battery systems allow the transfer of electricity from the commercial power service to the battery system for critical electrical loads. Battery backup systems do not typically provide power to ancillary devices on commercially powered facilities such as air conditioners, exhaust fans and lighting. Although in certain conditions, additional battery storage may be required to maintain equipment operating temperatures and lighting in the shelter.

- The batteries must be “deep cycle“ batteries designed for continuous charge and discharge with a minimum of 10 years of life under normal usage.
- The battery will consist of individual cells in molded, flame-retardant, durable, and impact-resistant cases.
- Valve-regulated lead-acid (VRLA), absorbed glass mat (AGM) and gel cell maintenance-free batteries are preferred.
- Automotive-type batteries and other flooded-cell batteries pose environmental and safety concerns and must not be used.
  - Servicing flooded-cell batteries requires the use of personal protective equipment and special battery safety equipment.
  - Flooded-cell lead-acid batteries must be equipped with an approved spill containment system to prevent damage caused by spilled battery electrolyte whenever electrolyte capacity is greater than 1 gallon.
  - Flooded-cell batteries require special ventilation systems to prevent the buildup of explosive hydrogen gas.
  - Explosion barriers are required in front of flooded-cell batteries based on volume.

GNB Absolyte GP
Absorbed Glass Mat

GNB SUNlyte 12-5000x
Valve-Regulated Lead-Acid

MK 8G22NF-DEKA
Gel Cell – Valve-Regulated

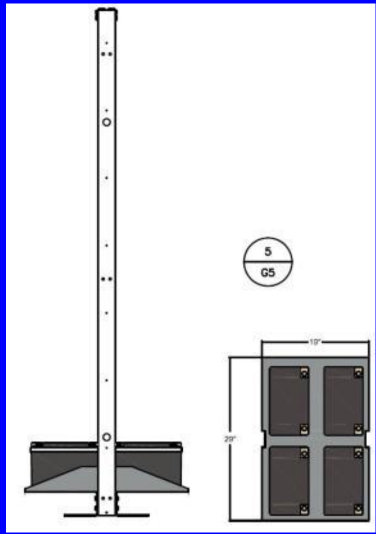
Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Battery Installation

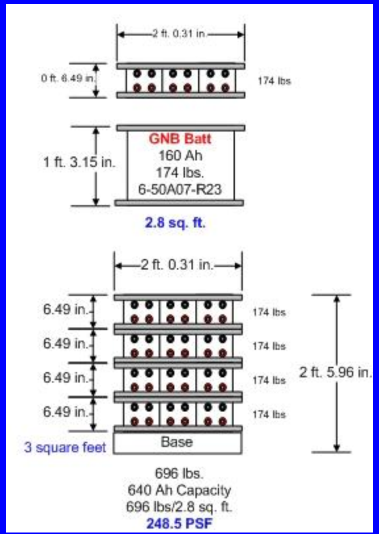
Section 26 33 00 – Battery Systems

- Batteries must be mounted on a battery rack, equipment rack, or be equipped with a metallic chassis that allows for fastening the batteries to the floor and/or stacking on top of one another.
  - Battery racks, enclosures, and shelves must be constructed to support the total weight of the batteries and other supporting equipment placed on them.
  - The equipment shelter or battery enclosure floor-loading specifications must be calculated and provisions made to support the total weight of the batteries on the installation surface.
  - Battery racks and stacked battery systems must be designed for the seismic zone in accordance with applicable requirements.
- The battery location must provide a minimum 36-inch deep, 30-inch wide work space in front of the batteries.
- Batteries must be equipped with insulated covers and/or insulated terminal protectors.
- ➢ Battery racks and chassis must be grounded to the single-point grounding system.
- ➢ Battery material safety data sheets (MSDSs) must be posted for all batteries at the facility.

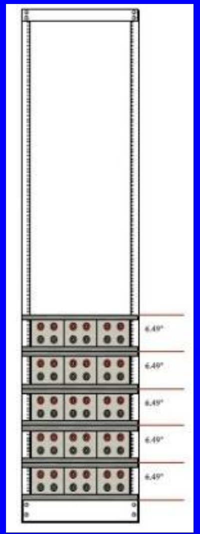
Standard Battery Rack



Batteries Mounted on Equipment Rack



GNB Absolyte Batteries Stacked



GNB Absolyte Batteries Rack-Mounted

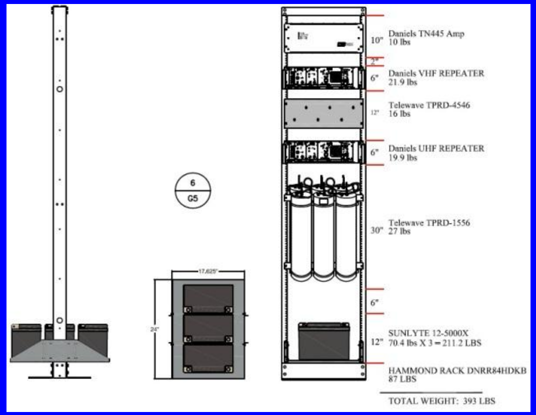
Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Battery Backup System Components

Section 26 33 00 – Battery Systems

Battery backup systems on commercially-powered radio facilities typically provide power to radios and other communications equipment during interruption of the commercial power service. Battery backup systems typically do not provide backup power to air conditioners, lighting, or other ancillary devices. In situations where power to all equipment and ancillary devices (including air conditioners) is required during commercial power interruption, a backup generator should be considered. Battery backup systems must include the following components:

- Batteries (see battery selection)
  - Batteries must be installed in a battery rack, on battery shelf in the equipment rack/cabinet, or have a chassis that allows for fastening the batteries in place to the floor.
- Commercial-grade AC-powered charger/controller.
  - The charger/controller must be equipped with control circuitry for the load (radio equipment), including overcurrent protection, battery voltage sensor, and a low-voltage load disconnect.
- An in-line fuse installed in series within 6 inches of the positive battery terminal or a fused disconnect switch installed within 36 inches of the batteries.
- DC-power distribution panel
  - The DC-power distribution panel provides a safe and organized means of splitting the DC power system into multiple circuits (wires), each providing power to multiple radio systems and ancillary devices.
- Ventilation.
  - Battery performance and service life are significantly affected by operating temperature. For full-rated performance and maximum service life, the battery temperature should be maintained close to 75° F.
  - At a minimum, a cross-ventilation system including an intake vent and exhaust fan or a Venturi cross-ventilation system must be installed.
  - Where practical, a commercial-grade HVAC system must be installed in the shelter or battery enclosure to maintain the temperature requirement.



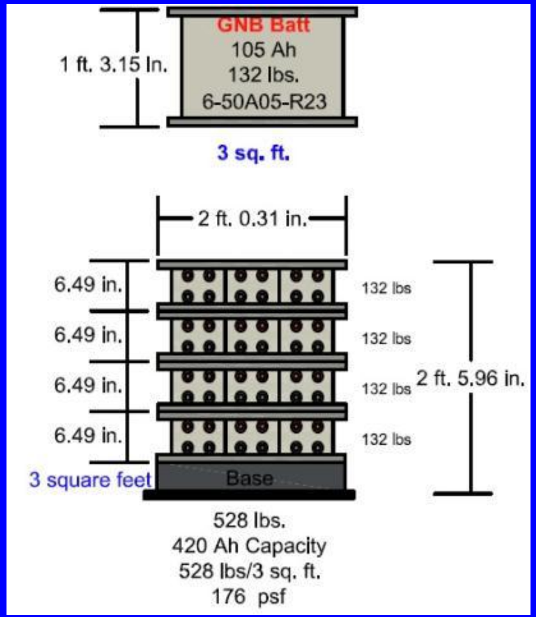


Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Battery Backup System Design

Section 26 33 00 – Battery Systems

Typically, a 2-hour battery backup provision is standard practice for shelter installations in urban areas. This is based on the assumption that 2 hours is the nominal amount of time in which a technician would be able to respond and correct a facility power problem. The backup duration should be adjusted on remote radio facilities based on extended travel time to the facility and the critical nature of the facility to provide continuous communications. Battery backup systems must include the following components:

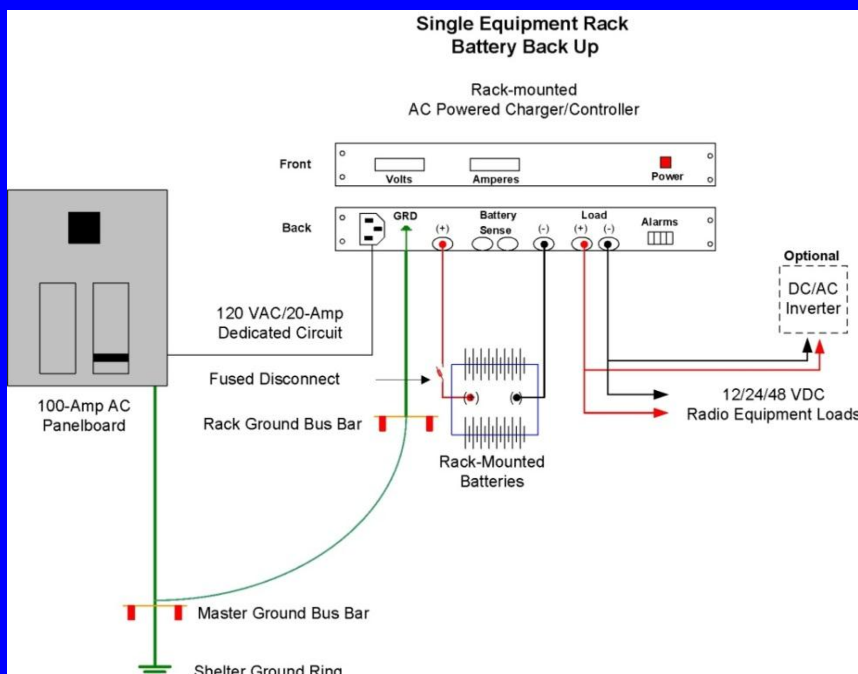
- To design a battery backup system capable of supplying the backup power needs, the designer needs the following information:
  - Typical Ampere-hours (Ah) used by equipment over a 24-hour period
    - 1 Ampere used continuously for 1 hour is 1 Ah
  - Voltage the power system must be capable of providing
    - Typically 12 Volts or 24 Volts
- The daily Ah rating is calculated as shown in the following example, given the characteristics for a single-repeater facility:
  - A single repeater requires 7 Amperes for Transmit (ATx) and 1 Ampere for Receive (ARx)
  - Duty Cycle: (Tx = 20%) <4.8 hrs. per day> (%Tx)
  - Duty Cycle: (Rx = 80%) <19.2 hrs. per day> (%Rx)
- Using the following formula: (ATx × %Tx) + (ARx × %Rx)] x 24 (hrs.) = average Ah required
- Determine total DC-power system rated capacity (Amperes and Watts)
  - Sum all active mode DC loads multiplied by 125% to calculate 80% load capacity
  - Battery systems and wiring must be designed 20% over the calculated electrical current draw by the equipment
- Determine total system battery backup capacity (Ah and Kilowatt-hours)
  - Calculate duty cycles for both active mode and idle mode on all devices
  - Determine "days of autonomy" required
    - Days of autonomy is the number of days the battery backup capacity will provide power to the radio system without recharging.

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

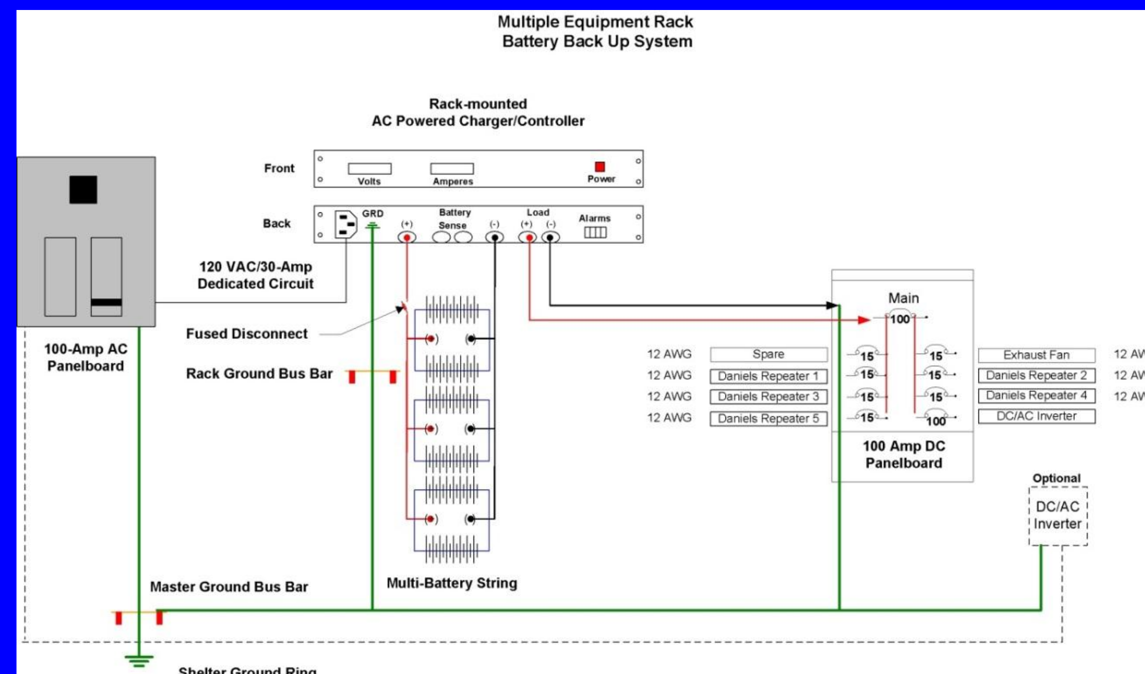
Typical Battery Backup (BBU) Drawings

Section 26 33 00 – Battery Systems

- Single equipment rack BBU includes the following:
  - Rack-mounted battery charger controller
  - One to four batteries mounted on shelves in the base of the radio equipment rack
- Multiple equipment rack BBU includes the following
  - Rack-mounted or wall-mounted battery charger controller
  - Multiple batteries connected in a large capacity string
  - Batteries mounted in a separate battery rack, stacked or mounted on shelves in a common equipment rack
  - Includes a DC-power distribution panel board



Single Equipment Rack BBU



Multiple Equipment Rack BBU

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

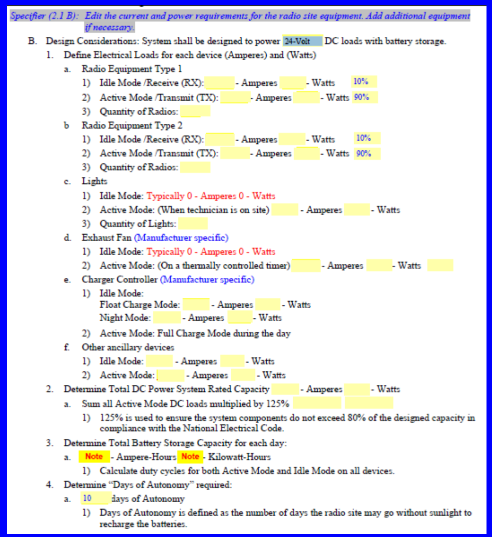
Photovoltaic Electrical Power – Designs

Section 26 31 00 – Photovoltaic Collector System

Developing a stand-alone photovoltaic power system should be contracted with a firm experienced in designing photovoltaic power systems. To design a system capable of supplying the radio facilities' power needs, the contracted firm needs the following information:

- Design Considerations: System is designed to power DC loads with battery storage
  - Define electrical loads for each device (Amperes) and (Watts)
    - Radio equipment
    - Idle mode/receive (RX)
    - Active mode/transmit (TX)
  - Lights
    - Idle mode is typically 0.0
    - Active mode when technician is on site
  - Exhaust fan
    - Idle mode is typically 0.0
    - Active mode on a thermally controlled timer
  - Charger controller
    - Idle mode is float charge mode and night mode
    - Active mode is full charge mode during the day
  - Other ancillary devices idle mode and active mode
- Determine total DC-power system rated capacity (Amperes and Watts)
  - Sum all active mode DC loads multiplied by 125% to calculate 80% load capacity
- Determine total system battery storage capacity (Ampere-Hours and Kilowatt-Hours)
  - Calculate duty cycles for both active mode and idle mode on all devices
  - Determine "days of autonomy" required
    - Days of autonomy is the number of days the battery storage capacity will provide power to the radio system without recharging

Pole-mounted Solar Panels



Specifier (2.1 B): Edit the current and power requirements for the radio site equipment. Add additional equipment if necessary.

B. Design Considerations: System shall be designed to power 24-Volt DC loads with battery storage.
1. Define Electrical Loads for each device (Amperes) and (Watts)
   a. Radio Equipment Type 1
      1) Idle Mode /Receive (RX): - Amperes - Watts 10%
      2) Active Mode /Transmit (TX): - Amperes - Watts 90%
      3) Quantity of Radios:
   b Radio Equipment Type 2
      1) Idle Mode /Receive (RX): - Amperes - Watts 10%
      2) Active Mode /Transmit (TX): - Amperes - Watts 90%
      3) Quantity of Radios:
   c. Lights
      1) Idle Mode: Typically 0 - Amperes 0 - Watts
      2) Active Mode: (When technician is on site) - Amperes - Watts
      3) Quantity of Lights:
   d. Exhaust Fan (Manufacturer specific)
      1) Idle Mode: Typically 0 - Amperes 0 - Watts
      2) Active Mode: (On a thermally controlled timer) - Amperes - Watts
   e. Charger Controller (Manufacturer specific)
      1) Idle Mode:
      Float Charge Mode: - Amperes - Watts
      Night Mode: - Amperes - Watts
      2) Active Mode: Full Charge Mode during the day
   f. Other ancillary devices
      1) Idle Mode: - Amperes - Watts
      2) Active Mode: - Amperes - Watts
2. Determine Total DC Power System Rated Capacity - Amperes - Watts
   a. Sum all Active Mode DC loads multiplied by 125%
      1) 125% is used to ensure the system components do not exceed 80% of the designed capacity in compliance with the National Electrical Code.
3. Determine Total Battery Storage Capacity for each day:
   a. Note - Ampere-Hours Note - Kilowatt-Hours
      1) Calculate duty cycles for both Active Mode and Idle Mode on all devices.
4. Determine "Days of Autonomy" required:
   a. 10 days of Autonomy
      1) Days of Autonomy is defined as the number of days the radio site may go without sunlight to recharge the batteries.

Printable Form

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Battery Storage Systems on Photovoltaic-powered Facilities

Section 26 33 00 – Battery Systems

Battery storage systems on photovoltaic-powered radio facilities provide power to the critical loads (radio equipment, exhaust fans, and lighting) at night and during periods with limited sunlight. Battery storage and charging capabilities must be adequate to supply power to the facility for 5 to 10 days without sun. Development of a stand-alone power system should be contracted with a firm experienced designing of alternate power systems.

- The batteries must be “deep-cycle“ designed for continuous charge and discharge with a minimum of 10 years of life under normal usage.
- The battery will consist of individual cells in molded, flame-retardant, durable, and impact-resistant cases.
- Valve-regulated lead-acid (VRLA), absorbed glass mat (AGM) and gel cell maintenance-free batteries are preferred.
- Automotive-type batteries and other flooded-cell batteries pose environmental and safety concerns and must not be used.
    - Servicing flooded-cell batteries requires the use of personal protective equipment and special battery safety equipment.
    - Flooded-cell lead-acid batteries must be equipped with an approved spill containment system to prevent damage caused by spilled battery electrolyte whenever electrolyte capacity is greater than 1 gallon.
    - Flooded-cell batteries require special ventilation systems to prevent the buildup of explosive hydrogen gas.
    - Explosion barriers are required in front of flooded-cell batteries based on volume.

GNB Absolyte GP
Absorbed Glass Mat

GNB SUNlyte 12-5000x
Valve-Regulated Lead-Acid

MK 8G22NF-DEKA
Gel Cell – Valve-Regulated

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Battery Storage System – Design

Section 26 33 00 – Battery Systems

Battery storage systems on photovoltaic-powered facilities must include the following components:

- Batteries
- Battery rack or chassis to allow fastening batteries in place
- Solar panels
- Photovoltaic-powered charger/controller equipped with control circuitry for the load (radio equipment), including overcurrent protection, battery voltage sensor, and a low-voltage load disconnect
- An inline fuse or fused disconnect switch installed within 6 inches of the positive battery terminal
- DC power distribution panel
  - The DC power distribution panel provides a safe and organized means of splitting the DC power system into multiple circuits (wires), each providing power to multiple radio systems and ancillary devices. Most DC power distribution panels allow fuses or resettable circuit breakers to be installed on each circuit to protect the system from electrical overload.
- Battery ventilation
  - Battery performance and service life are significantly affected by operating temperature. For full-rated performance and maximum service life, the battery temperature should be maintained close to 75° F
  - At a minimum, a cross-ventilation system including an intake vent and exhaust vent or a Venturi cross-ventilation system must be installed.
  - Where practical, a commercial-grade HVAC system must be installed in the equipment and/or battery enclosure to maintain the temperature requirement.

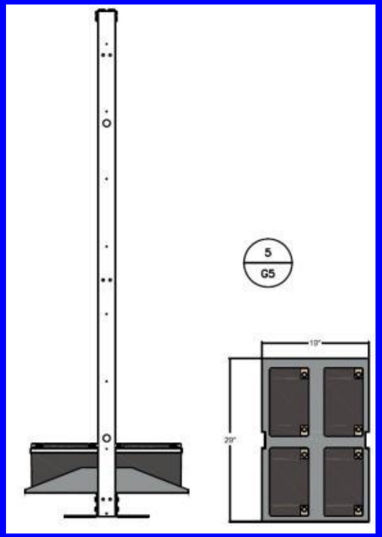
Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Battery Installation

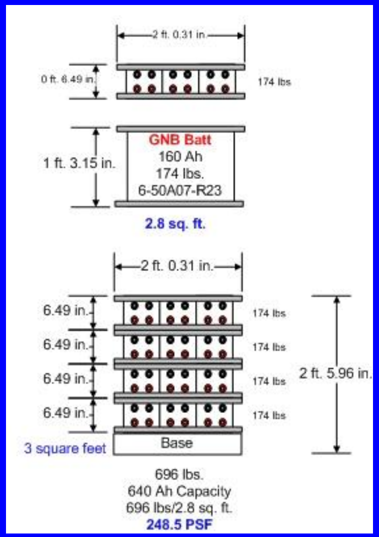
<u>Section 26 33 00 – Battery Systems</u>

- Battery installation
  - Batteries must be mounted on a battery rack, equipment rack, or be equipped with metallic chassis that allow fastening the batteries to the floor and/or stacking on top of one another.
  - Battery racks, enclosures, and shelves shall be constructed to support the total weight of the batteries and other supporting equipment placed on them.
  - The floor-loading specifications of the equipment shelter or battery enclosure must be calculated and provisions made to support the total weight of the batteries on the installation surface.
  - Battery racks and stacked battery systems must be designed for the seismic zone in accordance with applicable requirements.
  - The battery installation location must provide a minimum 36-inch deep, 30-inch wide work space in front of the batteries.
  - Batteries must be equipped with insulated covers and/or insulated terminal protectors.
  - Battery racks and chassis must be grounded to the single-point grounding system.
  - Battery material safety data sheets (MSDSs) must be posted for all batteries installed at a facility.

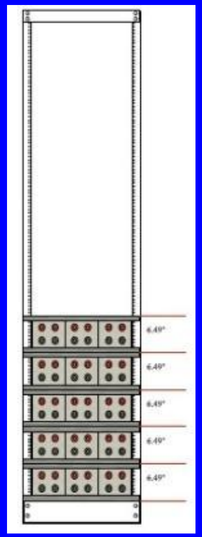
Standard Battery Rack



Batteries Mounted on Equipment Rack



GNB Absolyte Batteries Stacked



GNB Absolyte Batteries Rack-mounted

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Typical Component Power Consumption

Section 26 31 00 – Photovoltaic Collector System

The two most common repeaters observed in the field are the Daniels and Motorola Quantar. The Daniels is more widely used on photovoltaic powered radio facilities due to its lower current draw at idle and options for lower transmit power. The equation table below demonstrates the total daily power requirements for the for both repeater manufacturer's equipment.

- The Daniels repeater is calculated at two output power levels
  - 8 Watts (Standard) and with a 30-Watt power amplifier.
- The Motorola Quantar is calculated at the two lowest power configurations available for DC-power applications:
  - 25 Watts and 60 Watts
- Assumptions for repeater duty cycles
  - 20% transmit (TX)
  - 80% standby-receive (RX)
- Calculations for a typical exhaust fan
  - 16-inch diameter fan rated at 800 cubic feet per minute (CFM)
  - Provides complete air exchange in an 8-foot wide, 16-foot long, and 10-foot high shelter within 2 minutes.
- Calculations for interior shelter lighting
  - Six 15-Watt lights providing 900 Lumens

Ohm's law equation (formula): V = I × R and the power law equation (formula): P = I × V

DEVICES INCLUDED IN DESIGN	Daniels 8 Watt		Daniels 30 Watt		Motorola Quantar 25 Watt		Motorola Quantar 60 Watt		Thermally Controlled Exhaust Fan (800 CFM, 16 Inch)	DC powered Lighting on Timer Switch (6 ea.15 Watts, 900
Device Mode	TX	Standby RX	TX	Standby RX	TX	Standby RX	TX	Standby RX	*Active	**Active
(P) Power Consumption (Watts)	21.6	2.4	60	2.4	95	46	500	70	14.4	90
(V) System Voltage (VDC)	12	12	12	12	12	12	24	24	12	12
(I) Current Draw (Amps)	1.8	0.2	5.5	0.2	7.9	3.83	20.83	2.92	1.2	7.5
DAILY DUTY CYCLE (% of 24 hr Day)	20%	80%	20%	80%	20%	80%	20%	80%	13%	0%
DAILY DUTY CYCLE (Hours)	4.8	19.2	4.8	19.2	4.8	19.2	4.8	19.2	3.1	0.0
Average Ah required										
[(Tx × %Tx) + (RX × %Rx)] x 24 hrs =	4.2		4.94		75.116		60.23		3.744	0

*Fan Calculations Based on Air Exhange exchange volume: [Fan Active for 2 minutes, 4 times per hour = 8 minutes per hr 13%]
** Lights Only Active when Technician is on site

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Budgetary Photovoltaic Calculation Assumptions

Section 26 31 00 – Photovoltaic Collector System

For the purpose of demonstration, and budgeting, two typical photovoltaic systems with battery backup for the Daniels repeater are provided below. These are estimates only and should not be used for final designs. The two designs are for a 30-Ampere and a 60-Ampere photovoltaic charging system. The design assumptions are detailed below. The systems are designed to power 12-Volt DC loads with battery storage.

- **Radio Equipment**
  - Idle mode /receive (RX): = 2.4 Watts / 0.2 Amperes (80% Duty Cycle)
  - Active mode /transmit (TX): (20% Duty Cycle)
    - 8-Watt repeater = 21.6 Watts / 1.8 Amperes
    - 30-Watt repeater = 60 Watts / 5.5 Amperes

- **Lights** (6 each, 15 Watts, 900 Lumens)
  - Idle mode (off): typical 0 Watts/ 0 Amperes
  - Active mode (on): = 90 Watts / 7.5 Amperes (when technician is on site)

- **Exhaust Fan** (800 CFM, 16-inch diameter)
  - Idle mode (off): Typical 0 Watts/ 0 Amperes
  - Active mode (on): 14.4 Watts / 1.2 Amperes (13% Duty Cycle)

- **Charger Controller**
  - Idle mode: float-charge mode and night mode (not calculated)
  - Active mode: full-charge mode during the day (not calculated)

- System design factor = 125% of max load
- Days of Autonomy = 10
- Photovoltaic panel rating = 135 Watts each
- Battery capacity = 104 Ampere-Hours each

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

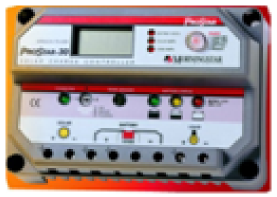
20-Ampere to 30-Ampere Photovoltaic System Calculations for up to Five Daniels 8-Watt Repeaters

The table below provides the calculations made for a photovoltaic charging and battery storage system based on the use of Daniels repeaters operating at 8 Watts transmit power. The calculations determine the following component requirements:

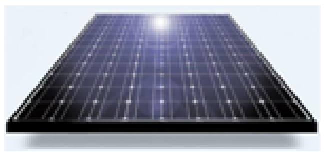
- Quantity of batteries required to sustain the radio equipment for 10 days of autonomy (sunless days)
- The system design maximum load (current draw) requirements measured in Amperes
  - The maximum load is the total of all electrical components (radios, lights, fans, etc.) if they were turned on simultaneously.
  - The system design load provides the minimum current rating for the system components including the charger/controller, wiring between solar panels and the charger/controller, output current from solar panels, and minimum sized panel boards
- Quantity of solar panels required to sustain the maximum load (current draw) and charge the batteries

Minimum Battery Capacity Daniels Repeater Standard 8 Watts	Consumption Ampere-Hours (Ah) Per Day				
	One Repeater	Two Repeaters	Three Repeaters	Four Repeaters	Five Repeaters
Repeater Total Daily Load (Ah)	4.20	8.40	12.60	16.80	21.00
Peripheral Equipment Daily Load (Ah)	3.74	3.74	3.74	3.74	3.74
Total Daily Load (Ah)	7.94	12.14	16.34	20.54	24.74
Days of Autonomy	10	10	10	10	10
Design Factor <Lowest Battery Temp 68 Degrees F>	1.39	1.39	1.39	1.39	1.39
Minimum Battery Capacity (Ah) Capacity (Ah) = Total Daily Load x Days of Autonomy x Design Factor	**110**	**169**	**227**	**286**	**344**
Power Consumption Per Day [kilowatt-hour (kWh)] Power Consumption (kWh) = Total Daily Load [Ah] x Voltage [24 VDC]	**265**	**405**	**545**	**685**	**825**
Quantity of 104 Ah Batteries Required for Days of Autonomy	1	2	2	3	3
System Design Load (Amperes)	**20.0**	**30.0**	**30.0**	**30.0**	**30.0**
Repeater Max Current Draw	1.8	3.60	5.40	7.20	9.00
Fan Max Current Draw	1.2	1.2	1.2	1.2	1.2
Lights Max Current Draw	7.5	7.5	7.5	7.5	7.5
Test Equipment Max Current Draw	5.0	5.0	5.0	5.0	5.0
TOTAL MAX CURRENT DRAW	**15.5**	**17.3**	**19.1**	**20.9**	**22.7**
DC Distribution Capacity **Design Factor** 125%	19	22	24	26	28
System Design Continuos Power Consumption (Watts)	**232.5**	**259.5**	**286.5**	**313.5**	**340.5**
Quantity of 135 Watt Solar Panels Required To Sustain Load	2	2	2	2	3

104 Ah Battery



30 Amp Charger/Controller



135 Watt Solar Panel

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

30-Ampere Photovoltaic System Drawing

30-Ampere Photovoltaic Distribution

The basic 30-Ampere system drawing below includes the following components:

- Three 135-Watt photovoltaic panels
- DC surge-protection devices at shelter entrance
- One 30-Ampere photovoltaic charger/controller module
- Three 104 Ampere-hour batteries
- One 100-Ampere electrical distribution panel with a 30-Ampere main circuit breaker
  - Five 10-Ampere circuit breakers for repeaters
  - One 15-Ampere circuit breaker for the exhaust fan
  - One 15-Ampere circuit breaker for lighting

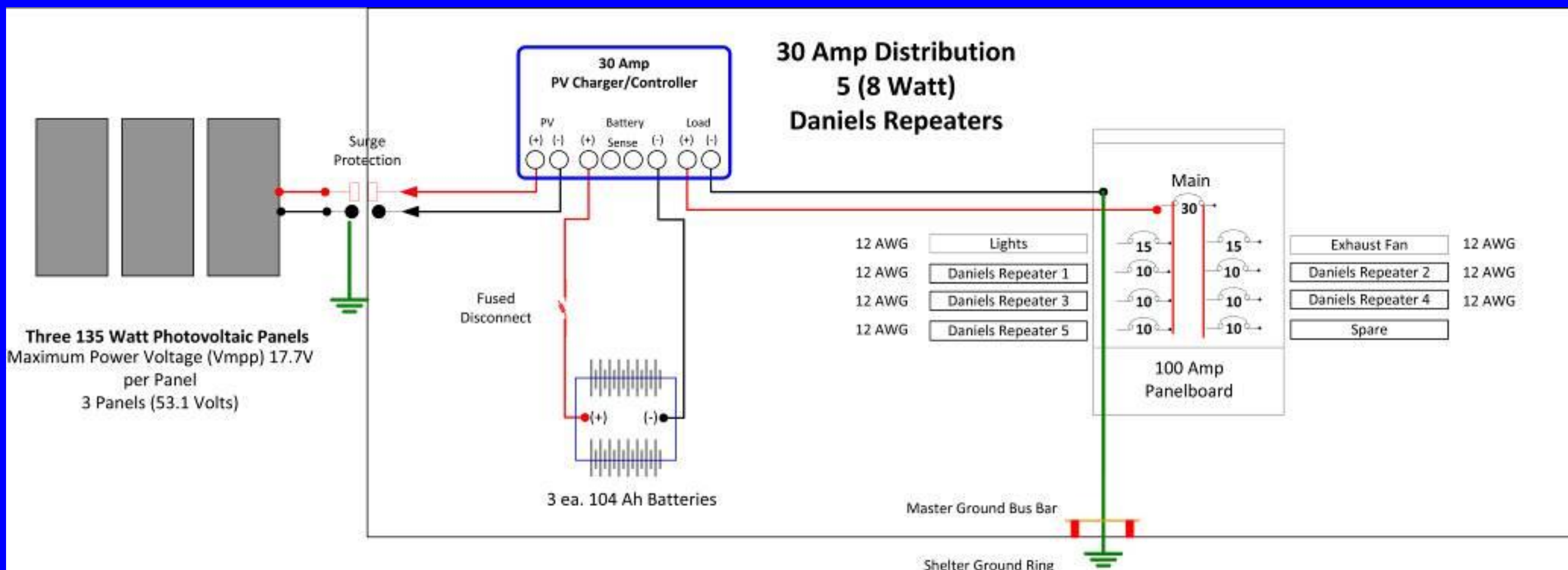


Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

30-Ampere to 60-Ampere Photovoltaic System Calculations for up to Five Daniels 30-Watt Repeaters

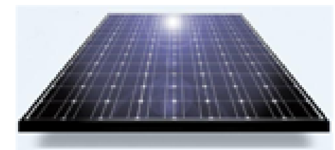
The table below provides the calculations made for a photovoltaic charging and battery storage system based on the use of Daniels repeaters operating with 30-Watt amplifiers. The calculations determine the following component requirements:

- Quantity of batteries required to sustain the radio equipment for 10 days of autonomy (sunless days)
- The system design maximum load (current draw) requirements measured in Amperes
  - The maximum load is the total of all electrical components (radios, lights, fans, etc.) if they were turned on simultaneously
  - The system design load provides the minimum current rating for the system components including the charger/controller, wiring between solar panels and the charger/controller, output current from solar panels, and minimum sized panel boards
- Quantity of solar panels required to sustain the maximum load (current draw) and charge the batteries.

Minimum Battery Capacity Daniels Repeater with 30 Watt Amplifier	Consumption Ampere-Hours (Ah) Per Day				
	One Repeater	Two Repeaters	Three Repeaters	Four Repeaters	Five Repeaters
Repeater Total Daily Load (Ah)	4.94	9.88	**14.82**	19.76	**24.70**
Peripheral Equipment Daily Load (Ah)	3.74	3.74	**3.74**	3.74	**3.74**
Total Daily Load (Ah)	**8.68**	13.62	**18.56**	23.50	**28.44**
Days of Autonomy	10	10	**10**	10	**10**
Design Factor <Lowest Battery Temp 68 Degrees F>	1.39	1.39	**1.39**	1.39	**1.39**
Minimum Battery Capacity (Ah) Capacity (Ah) = Total Daily Load x Days of Autonomy x Design Factor	**120.71**	**189.37**	**258.04**	**326.71**	**395.37**
Power Consumption Per Day [kilowatt-hour (kWh)] Power Consumption (kWh) = Total Daily Load [Ah] x Voltage [24 VDC]	**289.70**	**454.50**	**619.30**	**784.09**	**948.89**
Quantity of 104 Ah Batteries Required for Days of Autonomy	**1**	**2**	**2**	**3**	**4**
System Design Load - Amperes (Amps)	**30.0**	**30.0**	**45.0**	**45.0**	**60.0**
Repeater Max Current Draw	5.5	11.00	16.50	22.00	27.50
Fan Max Current Draw	1.2	1.2	1.2	1.2	1.2
Lights Max Current Draw	7.5	7.5	7.5	7.5	7.5
Test Equipment Max Current Draw	5.0	5.0	5.0	5.0	5.0
TOTAL MAX CURRENT DRAW	**19.2**	**24.7**	**30.2**	**35.7**	**41.2**
DC Distribution Capacity **Design Factor** 125%	24	31	38	45	52
System Design Continuos Power (Watts)	**288.0**	**370.5**	**453.0**	**535.5**	**618.0**
Quantity of 135 Watt Solar Panels Required To Sustain Load	**2**	**3**	**3**	**4**	**5**

104 Ah Battery

60-Amp Charger/Controller



135 Watt Solar Panel

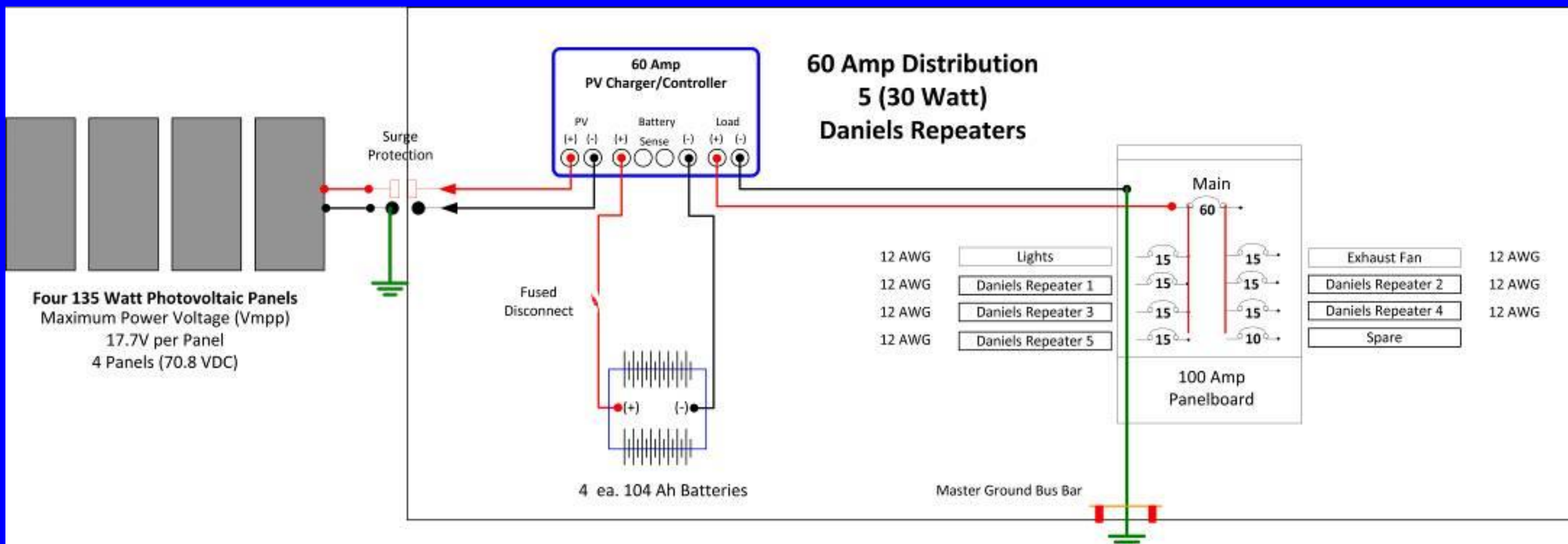
Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

60-Ampere Photovoltaic System Drawing

60-Ampere Photovoltaic Distribution

The basic 60-Ampere system drawing below includes the following components:

- Four 135-Watt photovoltaic panels
- DC surge-protection devices at shelter entrance
- One 60-Ampere photovoltaic charger/controller module
- Four 104 Ampere-hour batteries
- One 100-Ampere electrical distribution panel with a 60-Ampere main circuit breaker and the following:
  - Five 15-Ampere circuit breakers for repeaters
  - One 15-Ampere circuit breaker for the exhaust fan
  - One 15-Ampere circuit breaker for lighting



Photovoltaic-power System Grounding

- **Photovoltaic-power system components must be bonded and grounded as follows:**
  - Exposed, non-current-carrying, metal parts of solar panel frames, electrical equipment, and conduits must be grounded with #2 AWG or coarser, bare, solid, tinned or untinned, copper grounding conductors
  - Solar panels and supporting framework must be bonded together with #6 AWG or coarser, bare, solid, tinned, copper grounding conductors routed above grade or #2 AWG or coarser, bare, solid, tinned, copper grounding conductors where routed below grade or partially below grade
  - Roof Mount: If solar panels are roof mounted, the metallic portions of the solar panel framework must be grounded to the external grounding electrode system directly or bonded to the external ground bus bar with a #2 AWG or coarser, bare, solid, tinned or untinned, copper grounding conductor
  - Pole Mount: If solar panels are pole mounted, the solar panel framework must be bonded to the pole and the pole must be grounded to the external grounding electrode system with a #2 AWG or coarser, bare, solid, tinned or untinned, copper grounding conductor exothermically welded to the pole and the grounding system
  - Above grade grounding system connections must be joined using exothermic welding; UL 467-listed, irreversible, high-compression fittings compressed to a minimum of 12 tons of pressure, or as otherwise required by the specific component manufacturer
  - Connectors and fittings must be UL 467-listed for the purpose, for the type of conductor, and for the size and number of conductors used
  - Connecting hardware must be designed for the purpose, for the type of conductor, and for the size and number of conductors used

Listed Solar Panel Bonding Connector

Listed Two-Hole Irreversible Crimp Connector

Solar Panels Bonded with #6 AWG Minimum

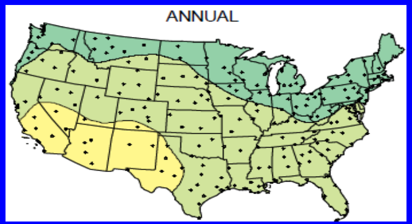
Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Maps of Average Daily Solar Radiation Annually

(Reference: National Renewable Energy Laboratory Renewable Resources Maps and Data Home Page)

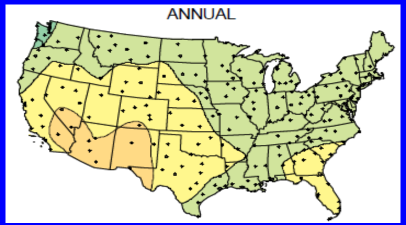
Maps of Average Daily Solar Radiation Annually

These maps show the general trends in the amount of solar radiation received in the United States. It is a spatial interpolation of solar radiation values derived from the 1961-1990 National Solar Radiation Data Base (NSRDB). The dots on the map represent the 239 sites of the NSRDB. Maps of average values are produced by averaging all 30 years of data for each site.



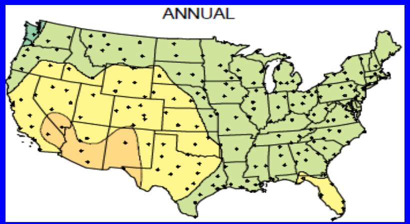
HORIZONTAL FLAT PLATE

A flat-plate collector facing south on a horizontal surface: This map shows how much solar radiation is received by a horizontal surface such as a solar pond.



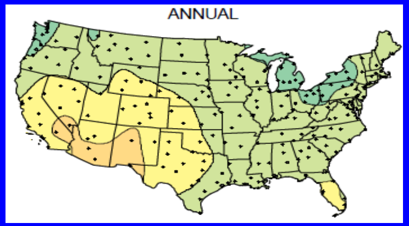
FLAT PLATE TILTED SOUTH EQUAL TO LATITUDE

A flat-plate collector facing south at a fixed tilt equal to the latitude of the site: Capturing the maximum amount of solar radiation throughout the year can be achieved using a tilt angle approximately equal to the facility's latitude.



FLAT PLATE TILTED SOUTH EQUAL TO LATITUDE -15 degrees

A flat-plate collector facing south at a fixed tilt equal to the latitude of the site minus 15 degrees: To optimize performance in the summer, this tilt angle is recommended.



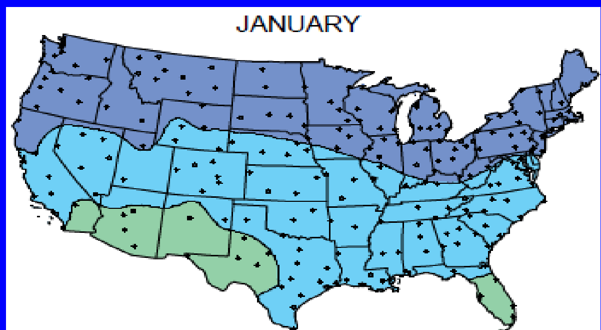
FLAT PLATE TILTED SOUTH EQUAL TO LATITUDE +15 degrees

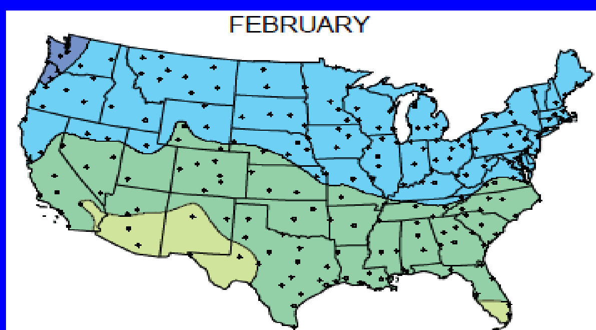
A flat-plate collector facing south at a fixed tilt equal to the latitude of the site plus 15 degrees: To optimize performance in the winter, this tilt angle is recommended.

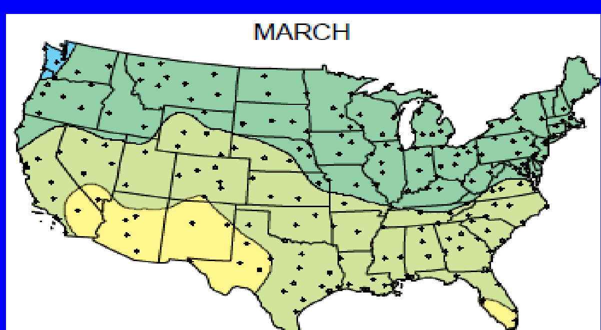
Maps of Average Daily Solar Radiation per Month (January to March)

(Reference: National Renewable Energy Laboratory Renewable Resources Maps and Data Home Page)

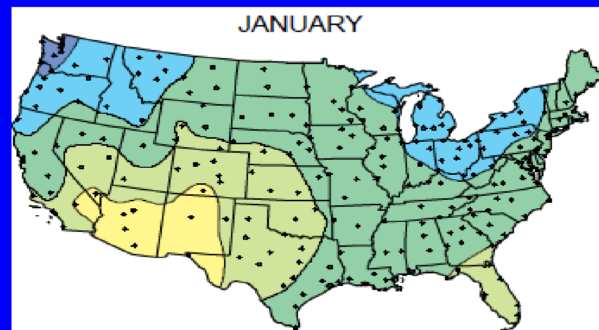
Horizontal Flat Plate
No Tilt

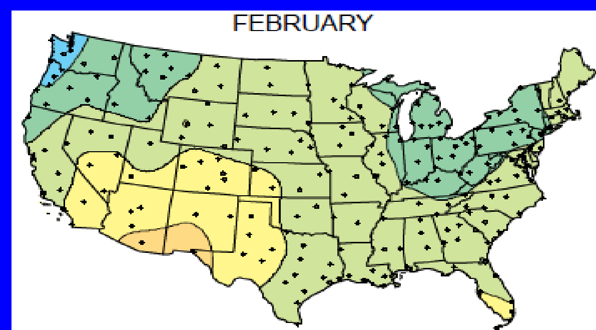


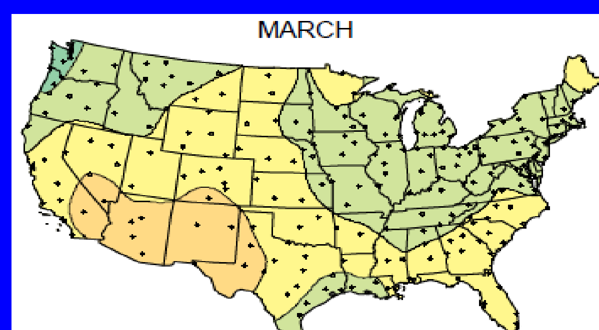




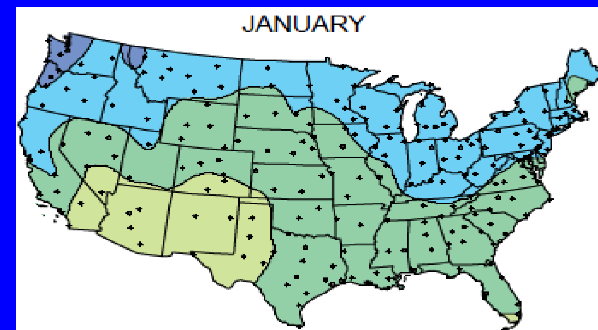
Year Round
Flat Plate tilted south equal to Latitude

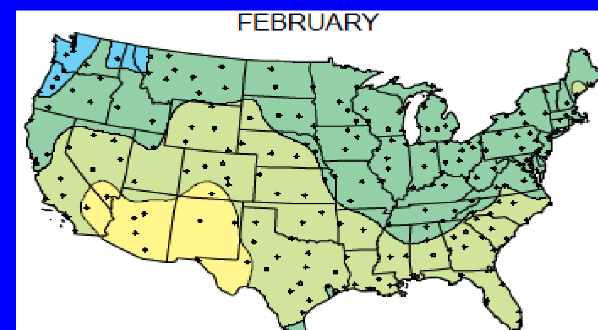


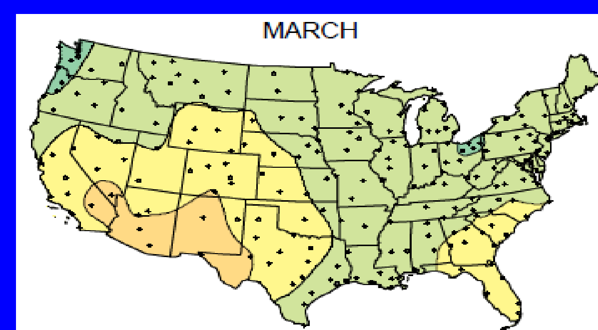




Summer
Flat Plate tilted south at Latitude – 15 degrees







$kWh/m^2/day$

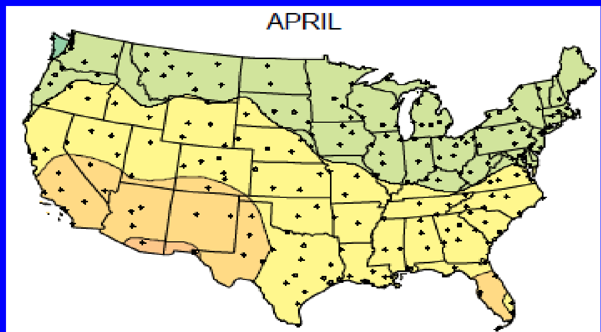
- 10 to 14
- 8 to 10
- 7 to 8
- 6 to 7
- 5 to 6
- 4 to 5
- 3 to 4
- 2 to 3
- 0 to 2
- none

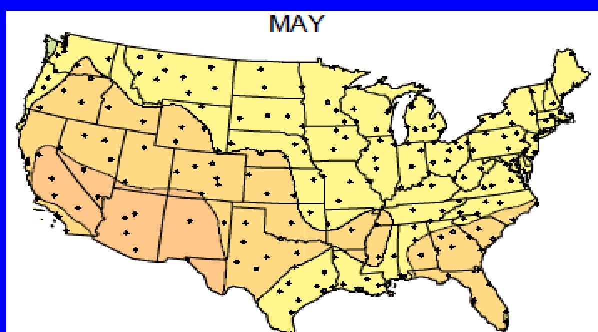
Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

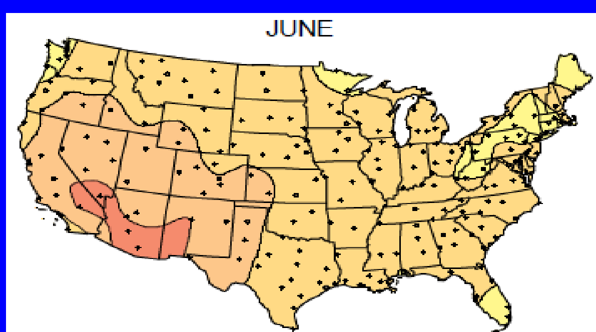
Maps of Average Daily Solar Radiation per Month (April to June)

(Reference: National Renewable Energy Laboratory Renewable Resources Maps and Data Home Page)

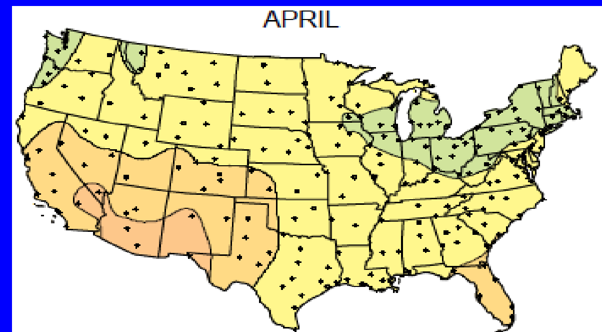
Horizontal Flat Plate
No Tilt

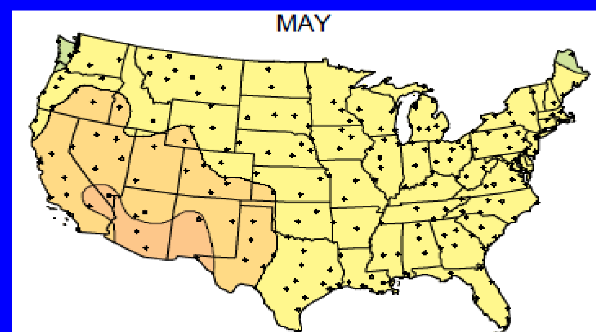


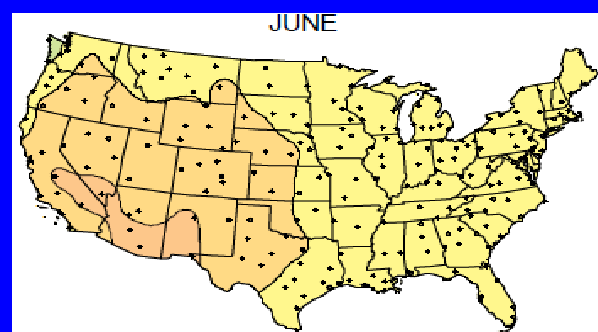




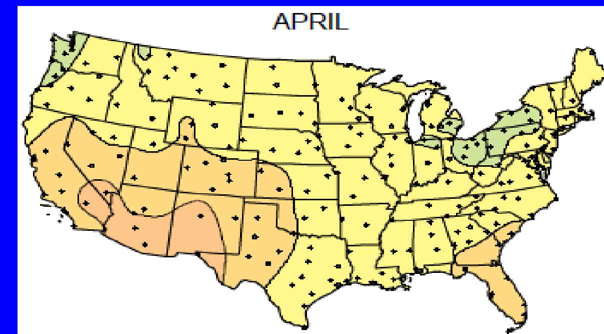
Year Round
Flat Plate tilted south equal to Latitude

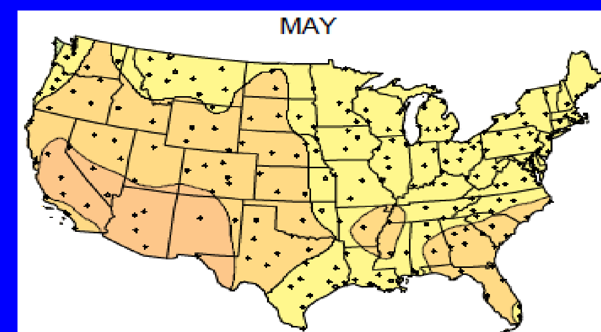


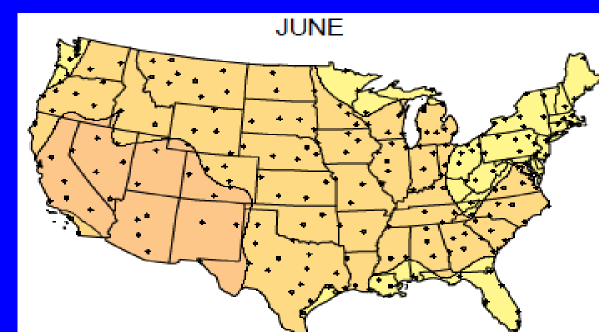




Summer
Flat Plate tilted south at Latitude – 15 degrees







kWh/m^2/day

- 10 to 14
- 8 to 10
- 7 to 8
- 6 to 7
- 5 to 6
- 4 to 5
- 3 to 4
- 2 to 3
- 0 to 2
- none

Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Maps of Average Daily Solar Radiation per Month (July to September)

(Reference: National Renewable Energy Laboratory Renewable Resources Maps and Data Home Page)

Horizontal Flat Plate
No Tilt

Year Round
Flat Plate tilted south equal to Latitude

Summer
Flat Plate tilted south at Latitude – 15 degrees

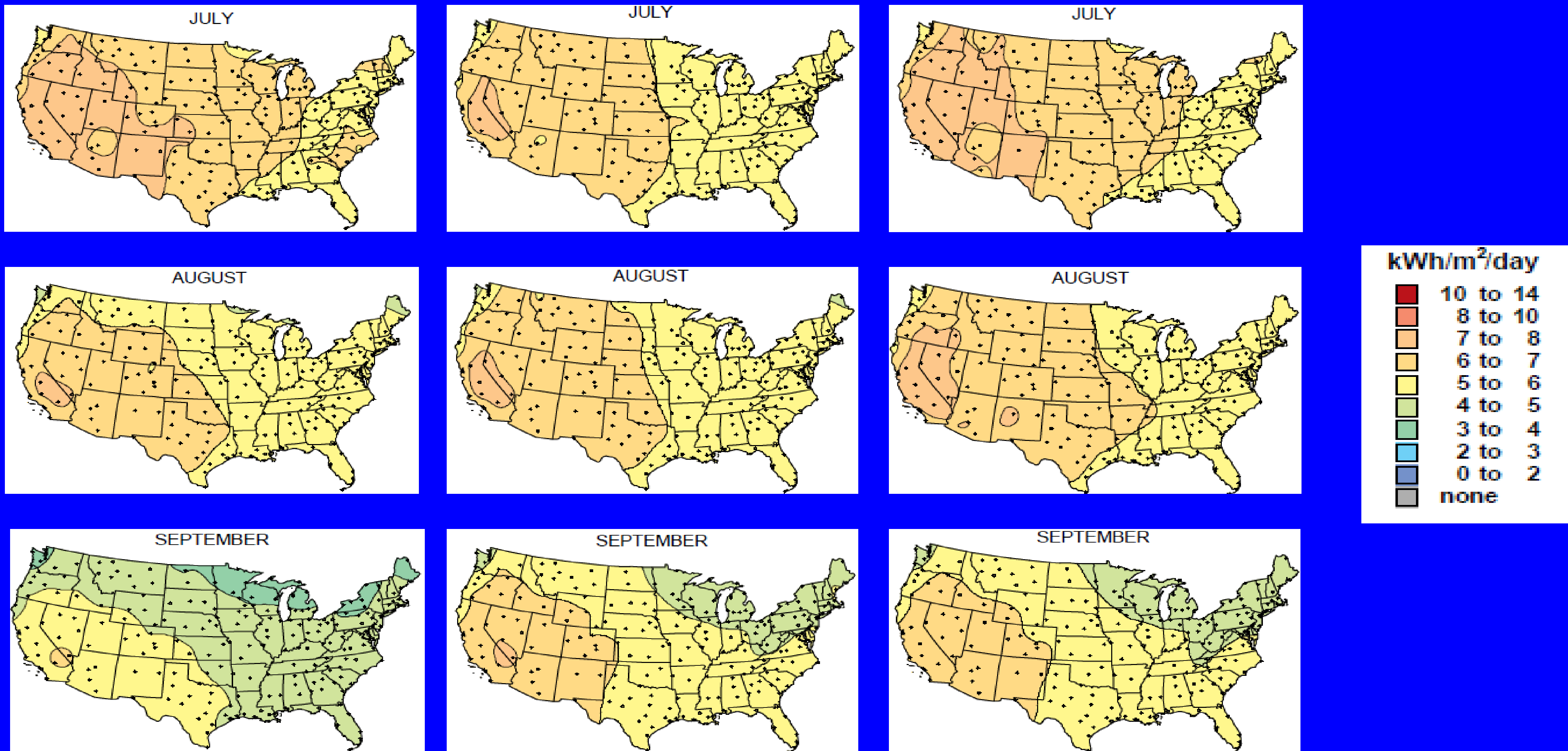


Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power

Maps of Average Daily Solar Radiation per Month (October to December)

(Reference: National Renewable Energy Laboratory Renewable Resources Maps and Data Home Page)

Horizontal Flat Plate
No Tilt

Year Round
Flat Plate tilted south equal to Latitude

Summer
Flat Plate tilted south at Latitude – 15 degrees

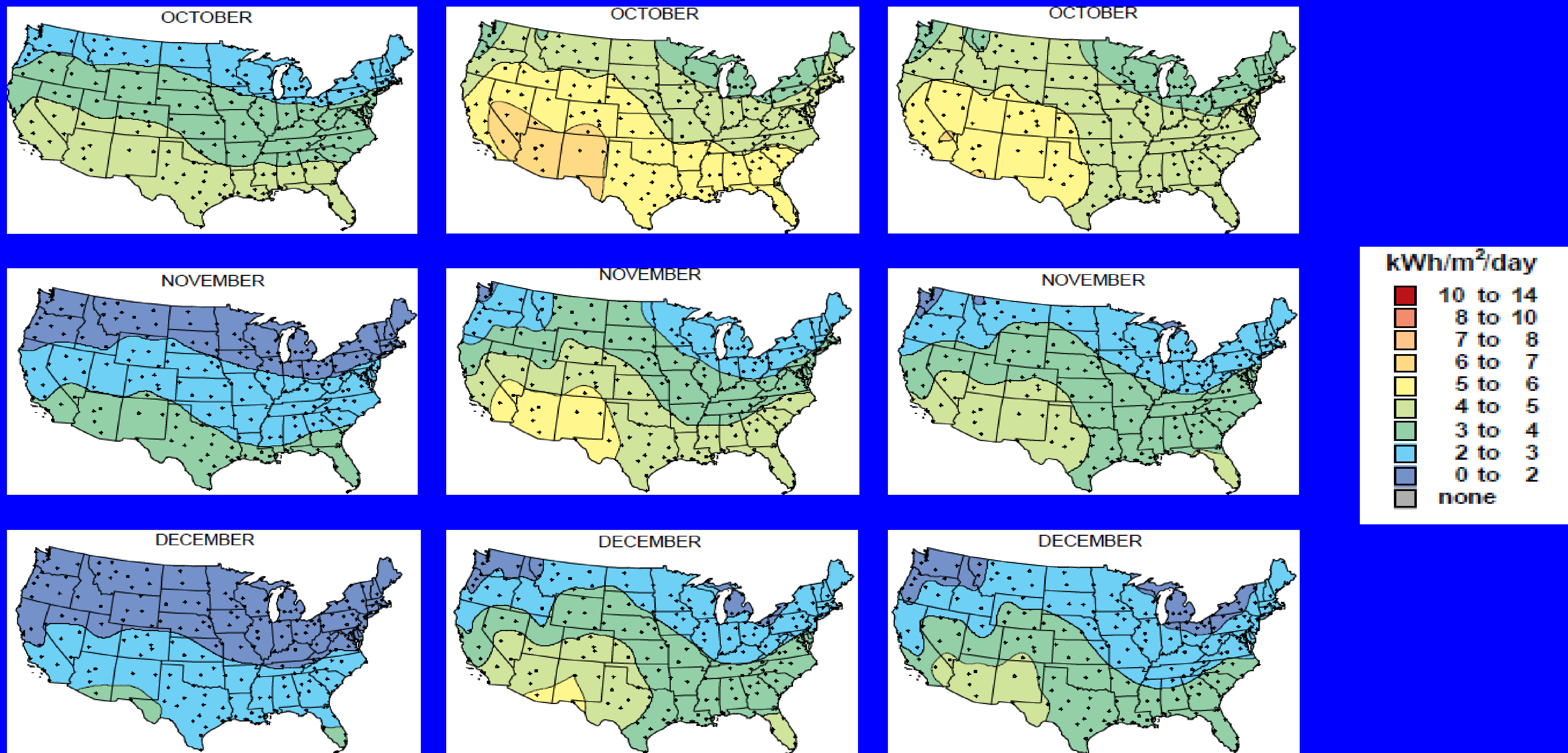


Table of Contents
Introduction
Reference Tables
Radio Site Designs
Prefabricated Shelter
Tower Designs
Aluminum Shelter with Articulating Antenna Mast
Outdoor Equipment Cabinet
Fiberglass Shelter with Antenna Radome
External Grounding
Internal Grounding
Commercial Electrical Power
Battery Backup Systems
Photovoltaic Electrical Power