EIA STRUCTURAL STANDARDS FOR STEEL TOWERS SUPPORTING ANTENNAS

1. GENERAL

1.01 This section consists of the attached copy of EIA Standard RS-222-C and is printed with the permission of the Electronic Industries Association (EIA). This standard was prepared largely by member companies of EIA with the assistance of a number of tower manufacturing firms.

1.02 This section is reissued to provide a revised edition of Standard RS-222-C dated March 1976. Revision arrows are not used since the changed material is preprinted and is provided as an attachment to this section.

1.03 Standard RC-222-C covers recommended design requirements and furnishes background information for steel antenna towers and antenna supporting structures for use within the Bell System.

Printed in U.S.A.

EIA RS-222-C

EIA STANDARD

Structural Standards for Steel Antenna Towers and Antenna Supporting Structures

RS-222-C
(Revision of RS-222-B)

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STRUCTURAL STANDARDS FOR STEEL ANTENNA TOWERS AND ANTENNA SUPPORTING STRUCTURES

(From EIA Standard RS-222-B and Standards Proposal No. 1182, formulated under the cognizance of EIA Subcommittee TR-14.7 on Towers.)

EXPLANATORY

The objective of these standards is to provide minimum criteria for specifying and designing Steel Antenna Towers and Antenna Supporting Structures. These standards are not intended to replace or supersede any applicable codes. These standards shall apply to Steel Antenna Towers and Antenna Supporting Structures for all classes of communications service: AM, CATV, FM, Microwave, TV, VHF and others.

SCOPE

This standard describes the requirements for steel antenna towers and antenna supporting structures.

1. MATERIAL

1.1 Standard

1.1.1 Structural steel, cast steel and steel forgings and bolts shall conform to specifications listed in the "Specification for the Design, Fabrication and Erection of Structural Steel for Buildings," issued by the American Institute of Steel Construction, hereinafter referred to as AISC specification as amended to date.

1.1.2 Steel tubes and/or pipe shall be of structural quality. The supplier of the material in question shall provide certified data concerning its mechanical and chemical characteristics.

1.1.3 Light gage steel structural members shall be of the quality specified by the American Iron and Steel Institute, "Specification for the Design of Cold-Formed Steel Structural Members," hereinafter referred to as AISI specification, as amended to date.

1.1.4 Bolts: All steel bolts shall conform to specifications listed in the AISC specification referred to in paragraph 1.1.1.

1.1.5 Bolt tension values and locking devices:

1.1.5.1 For friction-type connections all high-strength bolts shall be installed in accordance with the AISC above-mentioned "Specification for Structural Joints Using ASTM A325 or A490 Bolts," as amended to date.

(Note: Friction type connections shall not be applicable to oiled, painted, or galvanized contact surfaces unless the surfaces are prepared in accordance with paragraph 3(c) of the above mentioned specification.)

1.1.5.2 Where high-strength galvanized bolts are used for non-friction type connections, the bolt shall be tightened to a "snug tight" condition as defined in the AISC specification referred to in paragraph 1.1.5.1. A nut-locking device shall be used on each bolt.

1.1.5.3 Where high-strength bolts are used and tensioned in accordance with the AISC specifications referred to in paragraph 1.1.5.1, a nut-locking device is not required.

1.1.5.4 All bolts not specified herein will require a nut-locking device.

(Note: This section is not applicable to guy hardware.)

1.1.6 Where materials of other quality are used, the supplier must provide certified data concerning its mechanical and chemical characteristics

1.1.7 Materials other than steel are not included within the scope of this standard.

2. LOADING

2.1 Definitions

2.1.1 Dead Weight – The dead weight of the structure and all appurtenances attached thereto shall be included.

2.1.2 Ice Loading

2.1.2.1 Solid Ice – Density 56 lb per cubic foot.

2.1.2.2 Rime Ice – Density 30 lb per cubic foot.

2.1.3 Wind Loading – Wind loads shall be defined as the maximum forces and torques produced by a specified unit horizontal wind pressure acting on the tower, antenna assemblies, reflectors, guys, and other appurtenances attached thereto. In all cases, the specified ice coating shall be included as part of the projected area.

2.1.4 Appurtenances shall include but not be limited to guys, antenna assemblies, transmission lines, reflectors, conduit, lighting, climbing facilities, platforms, signs, anti-climbing devices.

2.1.5 Design load shall be the specified combination of wind, ice and dead weight applied to the tower.

2.1.5.1 Where terms other than Design Load are used in the preparation of a specification, they shall be synonymous with the term "Design Load."

(Note 1: Seismic loads are not included within the scope of this standard.)
(Note 2: Many specifications have used terms such as survival, shall withstand, etc. with an ambiguity in meaning and intent. Dividing the specified wind pressure by a factor of 1.65 for a design condition is considered inconsistent with good engineering practice.)

2.2 Standard

2.2.1 Structures when fully loaded shall be designed for the following minimum horizontal wind pressures in pounds per square foot, on flat surfaces.

Height Zone (Above Ground)	Wind Loading Zone A	B	C
Portion of tower under 300 feet	30	40	50
Portion of tower 300 feet–650 feet	35	48	60
Towers over 650 feet high shall be designed for a uniform wind pressure for their entire height	50	65	85

The loading zones refer to the map, Chart I "Wind Loading Zones" which is a part of this standard.

(Note 1: Wind pressures should be specified by "Wind Loading Zones." Wind pressures specified in pounds per square foot only shall be assumed to be uniform over the entire height of the tower. Wind pressures specified by both zone and pressures in pounds per square foot shall be designed for the more severe loading.)
(Note 2: For structures located where unusual conditions may be encountered consideration should be given to loads greater than those described above, in the preparation of the specifications.)
(Note 3: Towers greater than 300 feet and less than 650 feet in overall height would be designed for a minimum horizontal wind pressure of 30, 40, or 50 pounds per square foot on the portion of the tower below the 300 foot level and 35, 48, or 60 pounds per square foot for the portion of the tower above the 300 foot level.)

2.2.2 When ice is considered, it shall not be less than the minimum specified radial thickness on all members of the structure, including guys. Unless otherwise stated, ice shall be considered solid.

(Note: This standard does not specifically state an ice thickness requirement. If the tower is to be located where ice accumulation during a wind condition is expected, consideration should be given to an ice thickness requirement in the preparation of the Specification.)

2.2.3 In all cases, the pressure on cylindrical surfaces shall be computed as being 2/3 of that specified for flat surfaces. Refer to examples provided in Figures 1, 2, and 3.

2.2.4 For open face (latticed) structures of square cross section, the wind pressure shall be applied to 1.75 times the normal projected area of all members in one face. For open face (latticed) structures of triangular cross section, the wind pressure shall be applied to 1.5 times the normal projected area of all members in one face. For closed face (solid) structures, the wind pressure shall be applied to 1.0 times the normal projected area.

2.2.5 Provisions shall be made for all supplementary loadings caused by the attachment of guys, antennas, transmission and power lines, ladders, etc. The pressure shall be as described for the respective designs and shall be applied to the projected area of the construction.

In the event orientation of solid microwave antennas/reflectors is not given, the following minimum antenna load factors shall be used for guyed towers when more than one antenna is located at the

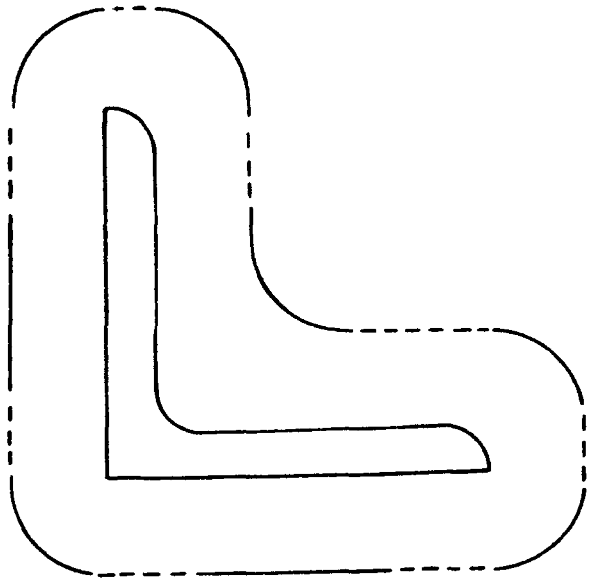


FIGURE 1

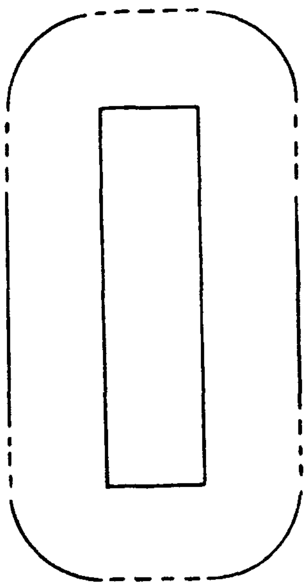


FIGURE 2

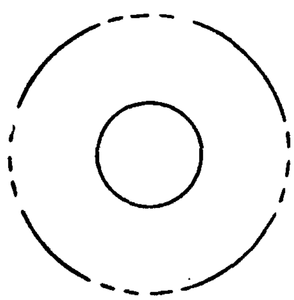


FIGURE 3

NOTE:

Radial ice accumulation means that ice builds uniformly on all surfaces to the radial thickness specified as illustrated.

The added projected area due to ice accumulation should be considered as cylindrical even though the bare projected area is flat. The 2/3 factor for cylindrical surfaces would then be applicable to this added projected area only. For circular sections, the 2/3 factor would apply to the full projected area.

same relative elevation on the tower:

1st antenna	100%	3rd antenna	65%
2nd antenna	75%	4th antenna	60%

For self-supporting towers, in the event orientation of solid microwave antennas/reflectors is not given, no reduction shall be considered.

2.2.6 The total load specified above shall be applied to the structure in the directions which will cause the maximum stress in the various members.

2.3 Method of Determination

Wind loads shall be calculated in accordance with the method specified in this standard.

Wind pressure is proportional to the square of the to the square of the actual wind velocity. Expressed as a formula, $P = KV^2$, where P is the wind pressure in pounds per square foot, K equals .004 and is the wind conversion factor and V is the actual wind velocity in miles per hour. This value of K includes a gust factor and a drag coefficient for flat surfaces.

3. STRESSES

3.1 Standard

3.1.1 The allowable unit stresses and the combined stresses resulting from the specified design loads for all structural members shall not exceed those specified in the AISC specifications with the following exceptions:

3.1.1.1 Wind loads shall be considered basic design loads with no increase in the basic allowable unit stresses.

3.1.1.2 Paragraph 1.16.6 of the AISC specification "Minimum Edge Distance in Line of Stress" shall not apply, however the L/d ratio shall not be less than 1.5. In bearing type connections on tension members, the individual bolt loading for connections having one or two bolts in a line parallel to the direction of stress shall not exceed the values given by the formulas below or that allowed for bearing and bolt shear by the AISC specification.

$$\text{IF } \left(1.5 < \frac{L}{d} < 1.75\right) \qquad P_{max} = \frac{d \cdot t \cdot F_u}{1.43}\left(\frac{L}{d} - 0.5\right)$$

$$\text{IF } \left(1.75 < \frac{L}{d} < 3\right) \qquad P_{max} = \frac{d \cdot t \cdot F_u}{2}\left(\frac{L}{d}\right)$$

Where:

P_{max} = Maximum allowable bolts load in KIPS

t = Material thickness in inches

F_u = Ultimate tensile strength in KSI

L = Distance in line of stress from center of end hole to edge in inches

d = Bolt diameter in inches

(Note: In some cases, materials with equal yield strengths may not have the same ultimate strengths.)

3.1.1.3 Table 1.16.5 of the AISC specification shall apply except that at sheared edges the minimum edge distance shall be 1.5 times the bolt diameter.

3.1.1.4 In the computation of allowable column buckling stresses, where effective length factors are considered less than 1.00 for members whose ends are attached by a single bolt, justification of the factor must be shown by test or computation for each individual member.

3.1.1.5 Bolt holes are not to be considered as pin holes, as referred to in AISC Section 1.5.1.1 for net sections in tension.

3.1.1.6 The conditions of the AISI specification shall apply for allowable unit and combined stresses associated with light gage steel. Wind loads shall be considered basic design loads with no increase in the basic allowable unit stresses.

(Note 1: In the computation of stresses of guyed towers, the displacement of the mast at guy levels should be considered.)
(Note 2: Communication towers are basically designed to resist the forces of nature caused by wind and ice. Any member having a calculable axial stress from these forces should be classified as a primary member as compared to a secondary member.)

3.1.2 The allowable unit stresses and design methods used for the design of reinforced concrete foundations and guy anchors shall conform to the requirements of the latest edition of the Standard Building Code Requirement for reinforced concrete (ACI-318) issued by the American Concrete Institute with the following exception.

3.1.2.1 Wind loads shall be considered basic design loads with no increase in the basic allowable unit stresses.

4. MANUFACTURE AND WORKMANSHIP

4.1 Standard

4.1.1 All manufacturing and workmanship shall be equal to best practice in modern manufacturing of similar materials.

4.1.2 All welding procedures shall be in accordance with the requirements of AISC and AISI.

5. FACTORY FINISH

5.1 Standard

5.1.1 Material when required shall be given a protective coating prior to shipment from the factory.

5.1.1.1 Material requiring protective painting shall be given at least one coat of good quality rust inhibitive paint.

5.1.2 All "Hot-dip" galvanized material shall receive a treatment of hot zinc after fabrication, in accordance with ASTM Designation A123 for structural materials, A153 for hardware, as amended to date.

5.1.1.3 Zinc coated guy strand shall be galvanized in accordance with ASTM-A475 or ASTM-A586.

5.1.2 All material requiring a protective coating and less than 3/16 inch thick, except guy strand, shall be hot-dipped galvanized.

6. PLANS AND MARKING

6.1 Standard

6.1.1 Complete plans and assembly drawings shall be supplied showing all the necessary marking and details for the proper assembly and installation of the material.

Tolerances for the proper layout and installation of the material and the foundation and anchors shall be shown on the plans.

6.1.1.1 Plumb – For guyed towers the maximum deviation from the true vertical shall be one part in 400. For self-supporting towers the maximum deviation from true vertical shall be one part in 250.

6.1.1.2 Linearity – For guyed towers the maximum deviation from a straight line between any two points shall not exceed one part in 1000.

6.1.2 All steel, except hardware shall be marked prior to painting or galvanizing with steel stencils or identified after painting or galvanizing by means of stamped or stencilled marks on metal tags wired to members, marks to have a height of not less than 5/8". The marks shall correspond with the marks on the assembly drawings.

7. FOUNDATIONS AND ANCHORS – CONCRETE OR OTHER MATERIAL

7.1 Definition

7.1.1 Standard Foundations and Anchors – Standard foundations and anchors are structures designed to support the specified loads of Secion 7.2.2 for normal soil conditions as defined in 7.1.2. Pile construction, roof installations, foundations or anchors designed for inundated soil conditions, etc., are not to be considered as standard.

7.1.2 Normal Soil – Normal soil is a cohesive type soil with an allowable net vertical bearing capacity of 4000 pounds per square foot and an allowable net horizontal pressure of 400 pounds per square foot per lineal foot of depth to a maximum of 4000 pounds per square foot. Rock, non-cohesive soils, or saturated or submerged soils are not to be considered as normal.

7.2 Standard

7.2.1 Standard foundations and anchors for self-supporting or guyed towers shall be designed for normal soil conditions.

7.2.2 All foundations and anchors should be designed for the maximum combined dead and live loading expected.

7.2.3 In uplift, it shall be assumed that the base of the standard foundation or anchors with an undercut or toe engages the frustum of an inverted pyramid or cone of earth whose sides form an angle of 30° with the vertical. Earth shall be considered to weigh 100 pounds per cubic foot and concrete, 150 pounds per cubic foot. The foundation or anchors shall have a minimum safety factor of 2 for uplift.

7.2.4 Where minor modification of standard design is necessary because actual soil conditions are not normal, the manufacturer shall furnish a foundation plan based on soil information supplied by the purchaser.

7.2.5 Under conditions requiring special engineering such as abnormal soil, pile construction, roof installations, etc., the manufacturer shall provide the necessary information so that proper foundations can be designed by the purchaser's engineer or architect.

7.2.6 Reduction in weight of materials dueto buoyancy caused by high water tables shall be considered. The soil propertics as affected by submerged conditions, saturated soil, etc., shall be considered in the foundation and anchor design utilizing recognized engineering methods with the safety factor as required in 7.2.3 above.

7.2.7 Foundation drawings shall show foundations and anchors designed to meet the conditions described above. These drawings shall show concrete strength and dimensions, reinforcing steel and embedded anchorage material, strength, size and location. Those foundations designed for standard soil conditions shall be so noted.

8. FACTOR OF SAFETY OF GUYS

8.1 Definition

The factor of safety of guys shall be calculated by dividing the catalog ultimate strength of the guy (modified by a factor as required by the type of connections and/or insulators used) by the maximum calculated tension design load.

8.2 Standard

The factor of safety of guys and their connections shall not be less than 2.5.

9. PRESTRESSING AND PROOF LOADING OF GUYS

9.1 Definition

Prestressing of guys is defined as the removal of the inherent constructional looseness of the guy under a sustained load. Proof loading is defined as the assurance of mechanical strength of the guys having factory assembled end connections.

9.2 Standard

Prestressing and proof loading are not normally recommended and will not be considered unless specified as a requirement. If required, prestressing and proof loading shall be performed in accordance with the guy manufacturer's recommendation.

(Note: For specialty type guyed structures, such as tall TV broadcast towers, consideration should be given to prestressing and proof loading.)

10. GUY TENSION (INITIAL GUY TENSION)

10.1 Definition

Initial guy tension shall be defined as the specified guy tension in pounds under no wind load conditions, at the guy anchor.

10.2 Standard

The manufacturer's assembly instructions shall include the recommended initial guy tension and/or sag at a specified temperature and wind velocity.

10.3 Method of Measurement

Initial tension may be measured by mechanical tensiometers, or be measurement of guy sag or by other suitable methods.

11. TOWER TWIST, SWAY, AND DISPLACEMENT

11.1 Definition

11.1.1 Tower Twist. Tower twist at any specified elevation shall be defined as the horizontal angular displacement of the tower from its no-wind load position at that elevation.

11.1.2 Tower Sway. Tower sway at any specified elevation shall be defined as the angular displacement of a tangent to the tower axis at that elevation from its no-wind load position at that elevation.

11.1.3 Tower Displacement. Tower displacement at any specified elevation shall be defined as the horizontal displacement of a point on the tower axis from its no-wind load position at that elevation.

11.2 Standard

The minimum standard shall be values based on a condition of no ice; a wind load of 20 pounds per square foot; and throughout a specified temperature range. These values shall be specified by the manufacturer or designer of the antenna system based on an overall allowable 10 dB degradation in radio frequency signal level.

(Note: A table of nominal twist and sway values for microwave tower-antenna-reflector systems is attached as supplemental reference information. See Table II. Also nomograms for beam widths are included for convenient reference.)

11.3 Method of Determination

11.3.1 Analytical Method. The preferred method is an analytical method.

11.3.2 Experimental Method. The twist, sway and displacement of the tower can be measured by suitable methods when caused by wind pressure or by the application of loads at suitable points.

11.3.3 The results of the determination will be provided by the manufacturer when specified in the contract.

12. PROTECTIVE GROUNDING

12.1 Definition

12.1.1 Tower grounding shall be defined as the means of establishing an electrical connection between the tower and the earth, adequate for lightning protection, high voltage or static discharges.

12.1.2 Primary ground is a conducting connection between the tower and earth or to some conducting body which serves in place of the earth.

12.1.3 Secondary ground is a conducting connection between a tower appurtenance and the tower.

12.2 Standard

12.2.1 All towers shall be directly grounded to a primary ground.

12.2.2 A minimum ground shall consist of two 5/8 inch diameter ground rods or equivalent driven not less than 8 feet into the ground adjacent to the tower base on opposite sides and bonded with a lead of not smaller than No. 6 copper connected to the nearest leg or to the metal base of the mast. A similar ground rod shall be installed at each guy anchor and similarly connected to the guy anchor except where steel or other metallic anchors are in direct contact with earth, no additional ground rods are required.

Self-supporting towers exceeding 5 feet in base width shall have one ground rod per leg installed as above.

(Note: Under conditions where the normal ground is considered inadequate, or additional ground rods are required or other additional grounding means are deemed necessary by the user, such additional grounding means should be subject to special arrangement. It may be necessary in some cases to take steps to insure electrical continuity of the tower from top to bottom, exclusive of transmission line.)

12.2.3 Any and all equipment on a tower shall be connected by a secondary ground.

12.2.4 Remote passive repeaters will be excepted from the above grounding requirements, except where required by contract.

13. CLIMBING AND WORKING FACILITIES

13.1 Definition

13.1.1 Climbing facilities are those tower components specifically designed and/or provided to permit tower access. Climbing facilities are fixed ladders, step bolts or tower members.

13.1.2 Climbing safety devices are any device, other than cages designed to minimize accidental falls, or to limit the length of such falls. They shall permit the person to ascend or descend the tower without having to continually manipulate the device or any part of the device. The climbing safety device usually consists of a carrier, safety sleeves and safety belts.

13.1.3 Working facilities are defined as work platforms and access runways. Hand or guard rails are horizontal barriers erected along a side or end of runways and platforms to prevent falls.

13.2 Standard (Note: The following criteria are intended as minimum requirements for new towers. It is not intended to replace or supersede applicable laws or codes.)

13.2.1 Climbing and working facilities and hand or guard rails shall be provided when specified by the purchaser.

13.2.2 Climbing facilities shall be designed to support a minimum 250 pounds concentrated live load.

13.2.2.1 When fixed ladders are specified as the climbing facility, they shall meet the following minimum requirements:

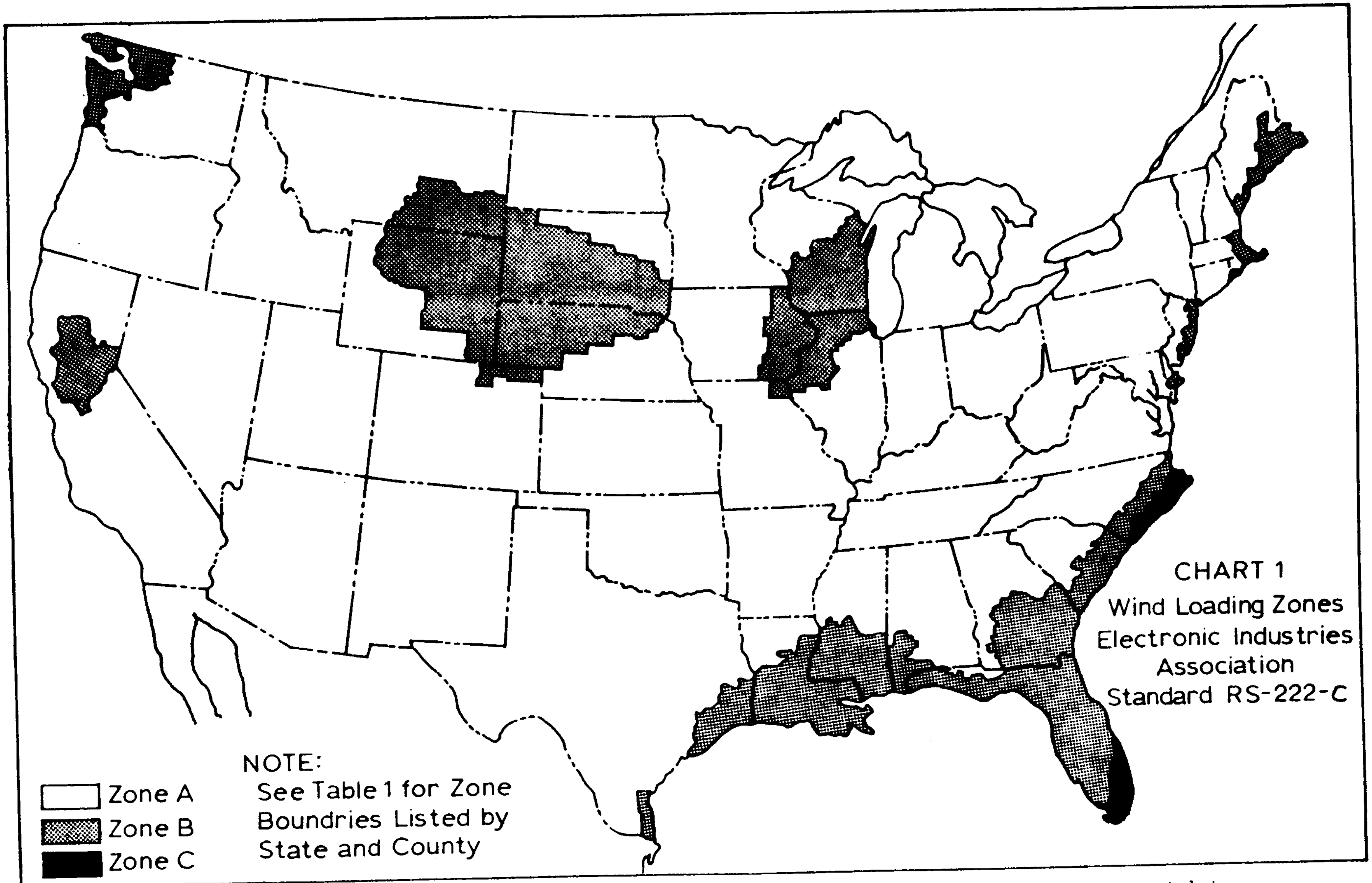
1. Side rail spacing–12 inch, minimum clear width.
2. Rung spacing–12 inch, minimum; 16 inch, maximum, center to center.
3. Rung diameter–5/8 inch, minimum.

13.2.2.2 When step bolts are specified they shall meet the following requirements:

1. Clear Width–4-½ inches, minimum
2. Spacing–12 inches, minimum, 18 inches maximum; center to center; alternately spaced. Supported antennas are excluded from this requirement.
3. Diameter–5/8 inches, minimum.

13.2.3 Climbing safety devices shall meet the design requirements of the American National Standards Institute (ANSI) A14.3 "Safety Code fo Fixed Ladders."

13.2.4 Support structures for working facilities shall be designed to support a uniform live load of 25 PSF but in no case shall the support structure be designed for less than a total live load of 500 pounds. Working surface, such as grating, shall be designed to support two 250 pound workers. These loads are not to be applied concurrently with wind and ice loads.



Location of wind loading zones based on 50 year mean recurrence interval chart from distribution of extreme winds in the United States by H. C. S. Thom published in the proceedings of the American Society of Civil Engineers. April 1960.

TABLE I

DESIGN WIND LOADING ZONES FOR STATES AND COUNTIES

(For Continental United States only)

(Tabulation by counties of zone boundaries for Chart I)

NOTE: States not listed and District of Columbia occur entirely within Zone "A".

State and County	*Zone*
ALABAMA	
Counties not listed	A
Baldwin	B
Clarke	B
Escambia	B
Mobile	B
Washington	B
CALIFORNIA	
Counties not listed	A
Amador	B
Butte	B
Calaveras	B
Colusa	B
Contra Costa	B
Eldorado	B
Glenn	B
Napa	B
Nevada	B
Placer	B
Sacramento	B
San Joaquin	B
Solano	B
Sutter	B
Tehama	B
Yolo	B
Yuba	B
COLORADO	
Counties not listed	A
Logan	B
Phillips	B
Sedgwick	B
Weld	B
DELAWARE	
Counties not listed	A
Sussex	B
FLORIDA	
Counties not listed	A
Alachua	B
Baker	B
Bay	B
Bradford	B
Brevard	B
Calhoun	B
Charlotte	B

State and County	*Zone*
FLORIDA (cont'd)	
Citrus	B
Clay	B
Collier	B
Columbia	B
De Soto	B
Dixie	B
Duval	B
Escambia	B
Flagler	B
Franklin	B
Glades	B
Gilchrist	B
Gulf	B
Hamilton	B
Hardee	B
Hendry	B
Hernando	B
Highlands	B
Hillsborough	B
Indian River	B
Jefferson	B
Lafayette	B
Lake	B
Lee	B
Leon	B
Levy	B
Liberty	B
Madison	B
Manatee	B
Marion	B
Martin	B
Nassau	B
Okaloosa	B
Okeechobee	B
Orange	B
Osceola	B
Pasco	B
Pinellas	B
Polk	B
Putnam	B
St. Johns	B
St. Lucie	B
Santa Rosa	B
Sarasota	B
Seminole	B
Sumter	B
Suwannee	B
Taylor	B
Union	B

State and County	Zone
FLORIDA (cont'd)	
Volusia	B
Wakulla	B
Walton	B
Washington	B
Broward	C
Dade	C
Monroe	C
Palm Beach	C
GEORGIA	
Counties not listed	A
Appling	B
Atkinson	B
Bacon	B
Ben Hill	B
Berrien	B
Bibb	B
Bleckley	B
Brantley	B
Brooks	B
Bryan	B
Bulloch	B
Camden	B
Candler	B
Charlton	B
Chatham	B
Clinch	B
Coffee	B
Colquitt	B
Cook	B
Crisp	B
Dodge	B
Dooly	B
Dougherty	B
Echols	B
Effingham	B
Emanuel	B
Evans	B
Glynn	B
Houston	B
Irwin	B
Jeff Davis	B
Johnson	B
Lanier	B
Laurens	B
Lee	B
Liberty	B
Long	B
Lowndes	B
Macon	B
McIntosh	B
Mitchell	B
Montgomery	B
Peach	B
Pierce	B
Pulaski	B
Screven	B
Sumter	B
Tattnall	B

State and County	Zone
GEORGIA (cont'd)	
Telfair	B
Thomas	B
Tift	B
Toombs	B
Treutlen	B
Turner	B
Twiggs	B
Ware	B
Wayne	B
Wheeler	B
Wilcox	B
Wilkinson	B
Worth	B
ILLINOIS	
Counties not listed	A
Boone	B
Bureau	B
Carroll	B
Cook	B
De Kalb	B
Du Page	B
Fulton	B
Hancock	B
Henderson	B
Henry	B
Jo Daviess	B
Kane	B
Knox	B
Lake	B
Lee	B
McDonough	B
McHenry	B
Mercer	B
Ogle	B
Rock Island	B
Stark	B
Stephenson	B
Warren	B
Whiteside	B
Winnebago	B
IOWA	
Counties not listed	A
Allamakee	B
Benton	B
Black Hawk	B
Buchanan	B
Cedar	B
Clayton	B
Clinton	B
Davis	B
Delaware	B
Des Moines	B
Dubuque	B
Fayette	B
Henry	B
Iowa	B
Jackson	B

State and County	Zone
IOWA (cont'd)	
Jefferson	B
Johnson	B
Jones	B
Keokuk	B
Lee	B
Linn	B
Louisa	B
Muscatine	B
Scott	B
Van Buren	B
Wapello	B
Washington	B
Winneshiek	B
LOUISIANA	
Counties not listed	A
Acadia	B
Allen	B
Ascension	B
Assumption	B
Avoyelles	B
Beauregard	B
Calcasieu	B
Cameron	B
Catahoula	B
Concordia	B
East Baton Rouge	B
East Feliciana	B
Evangeline	B
Grant	B
Iberia	B
Iberville	B
Jefferson	B
Jefferson Davis	B
Lafayette	B
La Fourche	B
La Salle	B
Livingston	B
Orleans	B
Plaquemines	B
Pointe Coupee	B
Rapides	B
St. Bernard	B
St. Charles	B
St. Helena	B
St. James	B
St. John The Baptist	B
St. Landry	B
St. Martin	B
St. Mary	B
St. Tammany	B
Tangipahoa	B
Tensas	B
Terrebonne	B
Vermilion	B
Vernon	B
Washington	B
West Baton Rouge	B
West Feliciana	B

State and County	Zone
MAINE	
Counties not listed	A
Cumberland	B
Hancock	B
Knox	B
Lincoln	B
Penobscot	B
Sagadahoc	B
Waldo	B
Washington	B
York	B
MARYLAND	
Counties not listed	A
Worcester	B
MASSACHUSETTS	
Counties not listed	A
Barnstable	B
Bristol	B
Dukes	B
Essex	B
Middlesex	B
Nantucket	B
Norfolk	B
Plymouth	B
Suffolk	B
MISSISSIPPI	
Counties not listed	A
Adams	B
Amite	B
Claiborne	B
Clarke	B
Copiah	B
Covington	B
Forrest	B
Franklin	B
George	B
Greene	B
Hancock	B
Harrison	B
Hinds	B
Jackson	B
Jasper	B
Jefferson	B
Jefferson Davis	B
Jones	B
Lamar	B
Lawrence	B
Lincoln	B
Marion	B
Pearl River	B
Perry	B
Pike	B
Rankin	B
Simpson	B
Smith	B
Stone	B
Walthall	B
Wayne	B
Wilkinson	B

State and County	Zone
MISSOURI	
Counties not listed	A
Clark	B
Knox	B
Lewis	B
Scotland	B
MONTANA	
Counties not listed	A
Big Horn	B
Carbon	B
Carter	B
Custer	B
Fallon	B
Powder River	B
Rosebud	B
Treasure	B
Yellowstone	B
NEBRASKA	
Counties not listed	A
Antelope	B
Arthur	B
Banner	B
Blaine	B
Boyd	B
Box Butte	B
Brown	B
Cedar	B
Cherry	B
Cheyenne	B
Dawes	B
Deuel	B
Garden	B
Grant	B
Holt	B
Hooker	B
Keith	B
Keyapaha	B
Kimball	B
Knox	B
Logan	B
Loup	B
McPherson	B
Morrill	B
Pierce	B
Rock	B
Scotts Bluff	B
Sheridan	B
Sioux	B
Thomas	B
NEW JERSEY	
Counties not listed	A
Atlantic	B
Bergen	B
Cape May	B
Hudson	B
Monmouth	B
Ocean	B

State and County	Zone
NORTH CAROLINA	
Counties not listed	A
Beaufort	B
Bertie	B
Bladen	B
Camden	B
Chowan	B
Columbus	B
Cumberland	B
Currituck	B
Duplin	B
Greene	B
Lenoir	B
Martin	B
Pasquotank	B
Perquimans	B
Pitt	B
Robeson	B
Sampson	B
Tyrrell	B
Washington	B
Wayne	B
Brunswick	C
Carteret	C
Craven	C
Dare	C
Hyde	C
Jones	C
New Hanover	C
Onslow	C
Pamlico	C
Pender	C
RHODE ISLAND	
Counties not listed	A
Newport	B
Washington	B
SOUTH CAROLINA	
Counties not listed	B
Beaufort	B
Berkeley	B
Charleston	B
Clarendon	B
Colleton	B
Dillon	B
Dorchester	B
Florence	B
Georgetown	B
Hampton	B
Horry	B
Jasper	B
Marion	B
Orangeburg	B
Williamsburg	B
SOUTH DAKOTA	
Counties not listed	A
Aurora	B

State and County	*Zone*
SOUTH DAKOTA (cont'd)	
Beadle	B
Bennett	B
Bon Homme	B
Brule	B
Buffalo	B
Butte	B
Charles Mix	B
Clay	B
Corson	B
Custer	B
Davison	B
Dewey	B
Douglas	B
Fall River	B
Faulk	B
Gregory	B
Haakon	B
Hand	B
Hanson	B
Harding	B
Hughes	B
Hutchinson	B
Hyde	B
Jackson	B
Jerauld	B
Jones	B
Kingsbury	B
Lawrence	B
Lincoln	B
Lyman	B
McCook	B
Meade	B
Mellette	B
Miner	B
Minnehaha	B
Pennington	B
Perkins	B
Potter	B
Sanborn	B
Shannon	B
Stanley	B
Sully	B
Todd	B
Tripp	B
Turner	B
Union	B
Washabaugh	B
Yankton	B
Ziebach	B
Lake	B
TEXAS	
Counties not listed	A
Angelina	B
Brazoria	B
Calhoun	B
Cameron	B
Chambers	B
Fort Bend	B
Galveston	B

State and County	*Zone*
TEXAS (cont'd)	
Hardin	B
Harris	B
Jasper	B
Jefferson	B
Kenedy	B
Kleburg	B
Liberty	B
Matagorda	B
Montgomery	B
Newton	B
Orange	B
Polk	B
Sabine	B
San Augustine	B
San Jacinto	B
Tyler	B
Wharton	B
Willacy	B
VIRGINIA	
Counties not listed	A
Accomack	B
Norfolk	B
Northampton	B
Virginia Beach	B
WASHINGTON	
Counties not listed	A
Clallam	B
Grays Harbor	B
Jefferson	B
Pacific	B
San Juan	B
Skagit	B
Wahkiakum	B
Whatcom	B
WISCONSIN	
Counties not listed	A
Adams	B
Brown	B
Calumet	B
Clark	B
Columbia	B
Crawford	B
Dane	B
Dodge	B
Door	B
Fond du Lac	B
Grant	B
Green	B
Green Lake	B
Iowa	B
Jackson	B
Jefferson	B
Juneau	B
Kenosha	B
Kewaunee	B

State and County	*Zone*
WISCONSIN (cont'd)	
LaCrosse	B
Lafayette	B
Manitowoc	B
Marathon	B
Marinette	B
Marquette	B
Milwaukee	B
Monroe	B
Oconto	B
Outagamie	B
Ozaukee	B
Portage	B
Racine	B
Richland	B
Rock	B
Sauk	B
Shawano	B
Sheboygan	B
Vernon	B
Walworth	B
Washington	B
Waukesha	B
Waupaca	B

State and County	*Zone*
WISCONSIN (cont'd)	
Waushara	B
Winnebago	B
Wood	B
WYOMING	
Counties not listed	A
Albany	B
Big Horn	B
Campbell	B
Converse	B
Crook	B
Goshen	B
Hot Springs	B
Johnson	B
Laramie	B
Natrona	B
Niobrara	B
Park	B
Platte	B
Sheridan	B
Washakie	B
Weston	B

TABLE OF ALLOWABLE TWIST AND SWAY VALUES

A	B	C	D	E	F	G	H	I
		Parabolic Antennas		Passive Repeaters		Periscope System Reflectors		
3 dB BEAM WIDTH $2\Theta_{HP}$ FOR PARABOLIC ANTENNA ONLY NOTE 8	DEFLECTION ANGLE, Θ AT 10 dB POINTS NOTE 1 NOTE 7	LIMIT OF ANTENNA MOVEMENT WITH RESPECT TO TOWER	LIMIT OF TOWER MOVEMENT TWIST OR SWAY AT ANTENNA ATTACHING POINT	LIMIT OF PASSIVE REPEATER SWAY NOTE 4 NOTE 5	LIMIT OF PASSIVE REPEATER TWIST NOTE 4	LIMIT OF REFLECTOR MOVEMENT WITH RESPECT TO TOWER	LIMIT OF TOWER TWIST AT REFLECTOR ATTACHING POINT	LIMIT OF TOWER SWAY AT REFLECTOR ATTACHING POINT
Degrees	Degrees	Degrees	Degrees	Degrees	Degrees	Degrees	Degrees	Degrees
5.8	5.0	0.4	4.6	3.5	2.5	0.2	4.8	2.3
5.6	4.8	0.4	4.4	3.3	2.4	0.2	4.6	2.2
5.4	4.6	0.4	4.2	3.2	2.3	0.2	4.4	2.1
5.1	4.4	0.4	4.0	3.0	2.2	0.2	4.2	2.0
4.9	4.2	0.4	3.8	2.9	2.1	0.2	4.0	1.9
4.7	4.0	0.3	3.7	2.8	2.0	0.2	3.8	1.8
4.4	3.8	0.3	3.5	2.6	1.9	0.2	3.6	1.7
4.2	3.6	0.3	3.3	2.5	1.8	0.2	3.4	1.6
4.0	3.4	0.3	3.1	2.3	1.7	0.2	3.2	1.5
3.7	3.2	0.3	2.9	2.2	1.6	0.2	3.0	1.4
3.5	3.0	0.3	2.7	2.1	1.5	0.2	2.8	1.4
3.4	2.9	0.2	2.7	2.0	1.45	0.1	2.8	1.3
3.3	2.8	0.2	2.6	1.9	1.4	0.1	2.7	1.3
3.1	2.7	0.2	2.5	1.8	1.35	0.1	2.6	1.25
3.0	2.6	0.2	2.4	1.8	1.3	0.1	2.5	1.2
2.9	2.5	0.2	2.3	1.7	1.25	0.1	2.4	1.15
2.8	2.4	0.2	2.2	1.6	1.2	0.1	2.3	1.1
2.7	2.3	0.2	2.1	1.6	1.15	0.1	2.2	1.05
2.6	2.2	0.2	2.0	1.5	1.1	0.1	2.1	1.0
2.5	2.1	0.2	1.9	1.4	1.05	0.1	2.0	0.95
2.3	2.0	0.2	1.8	1.4	1.0	0.1	1.9	0.9
2.2	1.9	0.2	1.7	1.3	0.95	0.1	1.8	0.85
2.1	1.8	0.2	1.6	1.2	0.90	0.1	1.7	0.8
2.0	1.7	0.2	1.5	1.1	0.85	0.1	1.6	0.75
1.9	1.6	0.2	1.4	1.1	0.8	0.1	1.5	0.7
1.7	1.5	0.2	1.3	1.0	0.75	0.1	1.4	0.65
1.6	1.4	0.2	1.2	0.9	0.7	0.1	1.3	0.6
1.5	1.3	0.1	1.2	0.9	0.65	0.1	1.2	0.55
1.4	1.2	0.1	1.1	0.8	0.6	0.1	1.1	0.5
1.3	1.1	0.1	1.0	0.7	0.55	0.1	1.0	0.45
1.2	1.0	0.1	0.9	0.7	0.5	0.1	0.9	0.4
1.1	0.9	0.1	0.8	0.6	0.45	0.1	0.8	0.35
0.9	0.8	0.1	0.7	0.5	0.4	0.1	0.7	0.3
0.8	0.7	0.1	0.6	0.4	0.35	0.1	0.6	0.25
0.7	0.6	0.1	0.5	0.4	0.3	0.1	0.5	0.2
0.6	0.5	0.1	0.4	0.3	0.25	0.1	0.4	0.15
0.5	0.4	0.1	0.3	0.2	0.2	0.07	0.3	0.13
0.3	0.3	0.05	0.25	0.2	0.15	0.05	0.25	0.10
0.2	0.2			0.14	0.1			
0.1	0.1			0.07	0.05			

Only for configuration where antenna is directly under the reflector.

NOTES:

1. Values for columns "A" and "B" will be available from the manufacturer(s) of the antenna system components for the support structure designer, or the user of the antenna system will specify the appropriate value desired for column "B"

2. Limits of beam movement for twist or sway (treated separately in most analyses) will be the sum of the appropriate figures in columns C & D, **G & H, and G & I. Columns G, H, and I apply to a vertical periscope configuration.**

3. It is not intended that the values in this table imply an accuracy of beam width determination or structural rigidity calculation beyond known practical values and computational procedures. For most microwave towers it is not practical to specify a calculated structural rigidity of less than ¼° twist or sway with 20psf loading

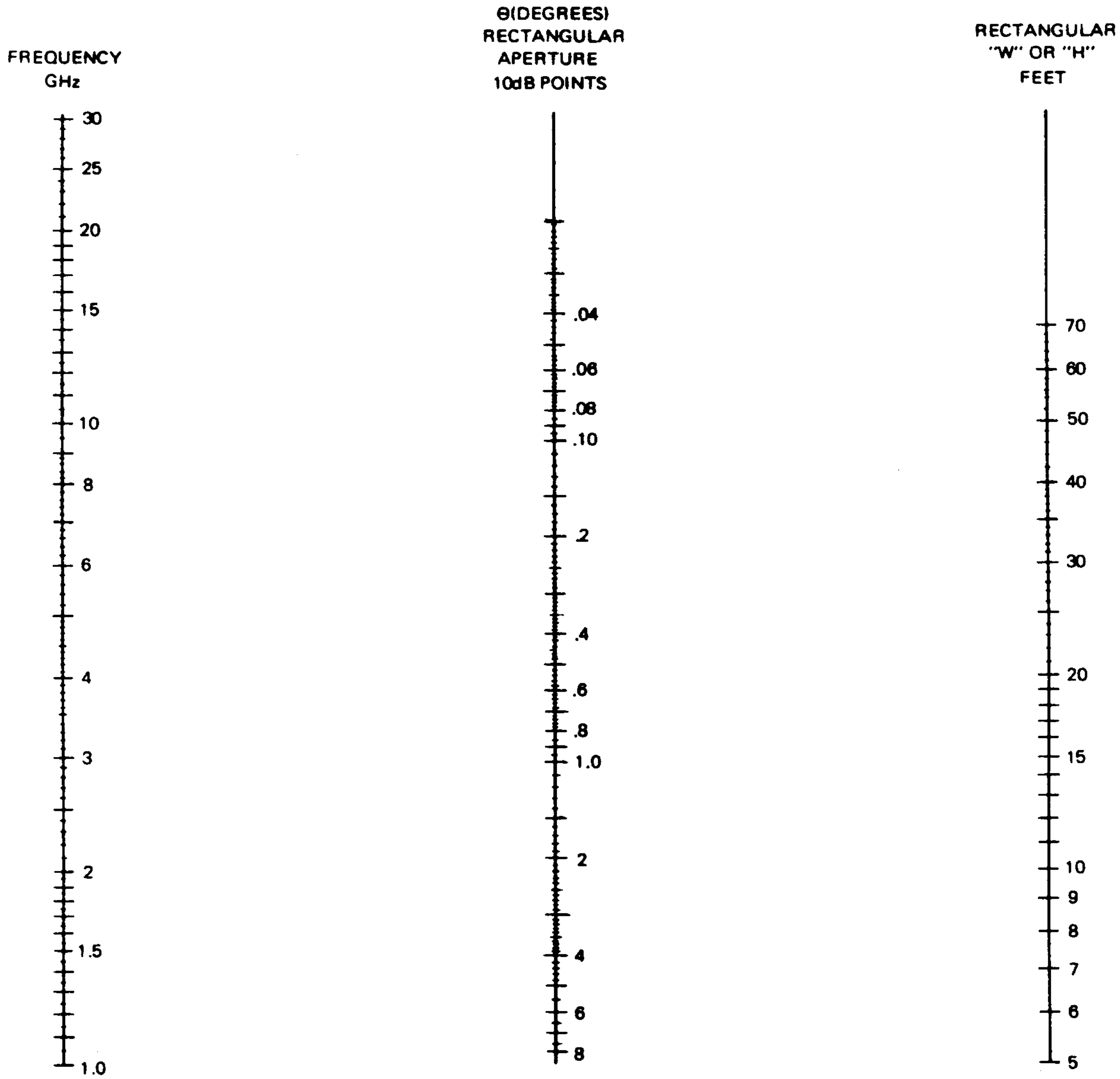
4. For passive repeaters the allowable twist and sway values are assumed to include the effects of all members contributing to the rotation of the face under wind load. For passives not elevated far above ground (approximately 5 to 20 ft. clearance above ground) the tower and reflecting face supporting elements are considered an integral unit; therefore, separating the tower portion of the deflection is only meaningful when passives are mounted on conventional microwave towers.

5. The allowable sway for passive repeaters is considered to be 1.4 times the allowable twist to account for the amount of rotation of the face about a horizontal axis through the face center and parallel to the face compared to the amount of beam rotation along the direction of the path as it deviates from the plane of the incident and reflected beam axes.

6. Linear horizontal movement of antennas and reflectors in the amount experienced for properly designed microwave antenna system support structures is not considered a problem (no significant signal degradation attributed to this movement).

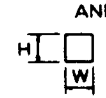
7. For systems using a frequency of 450 MHz the half power beam widths may be nearly 20 degrees for some antennas, however structures designed for microwave relay systems will usually have an inherent rigidity less than the maximum 5 degree deflection angle shown on the chart.

8. The 3dB beamwidths, $2\Theta_{HP}$, in column "A" are shown for convenient reference to manufacturers' standard published antenna information. The minimum deflection reference for this standard is the allowable total deflection angle, Θ, at the 10 dB points.



FLAT FACE REFLECTOR
ILLUMINATION
UNIFORM AMPLITUDE
AND PHASE

PLAN OR ELEVATION OF
FLAT FACE REFLECTORS



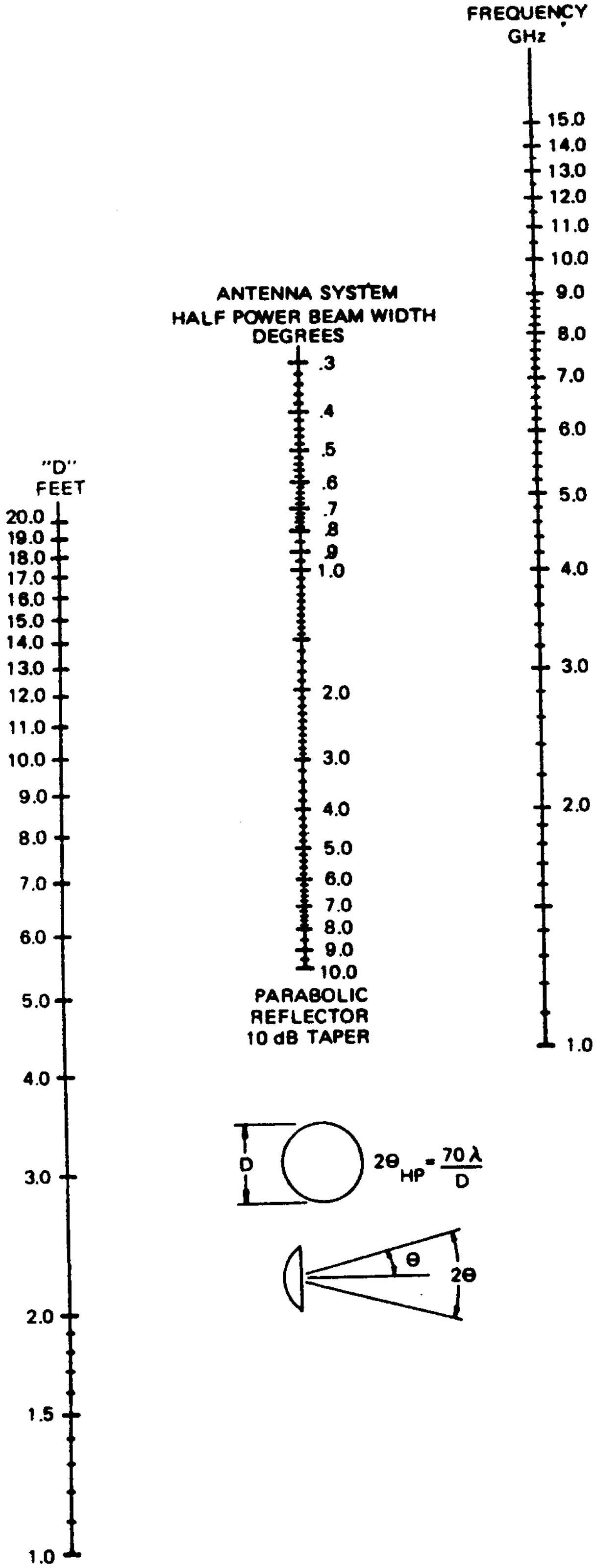
$\Theta = \frac{44\lambda}{W \text{ or } H}$

RECTANGULAR OR
SQUARE APERTURE

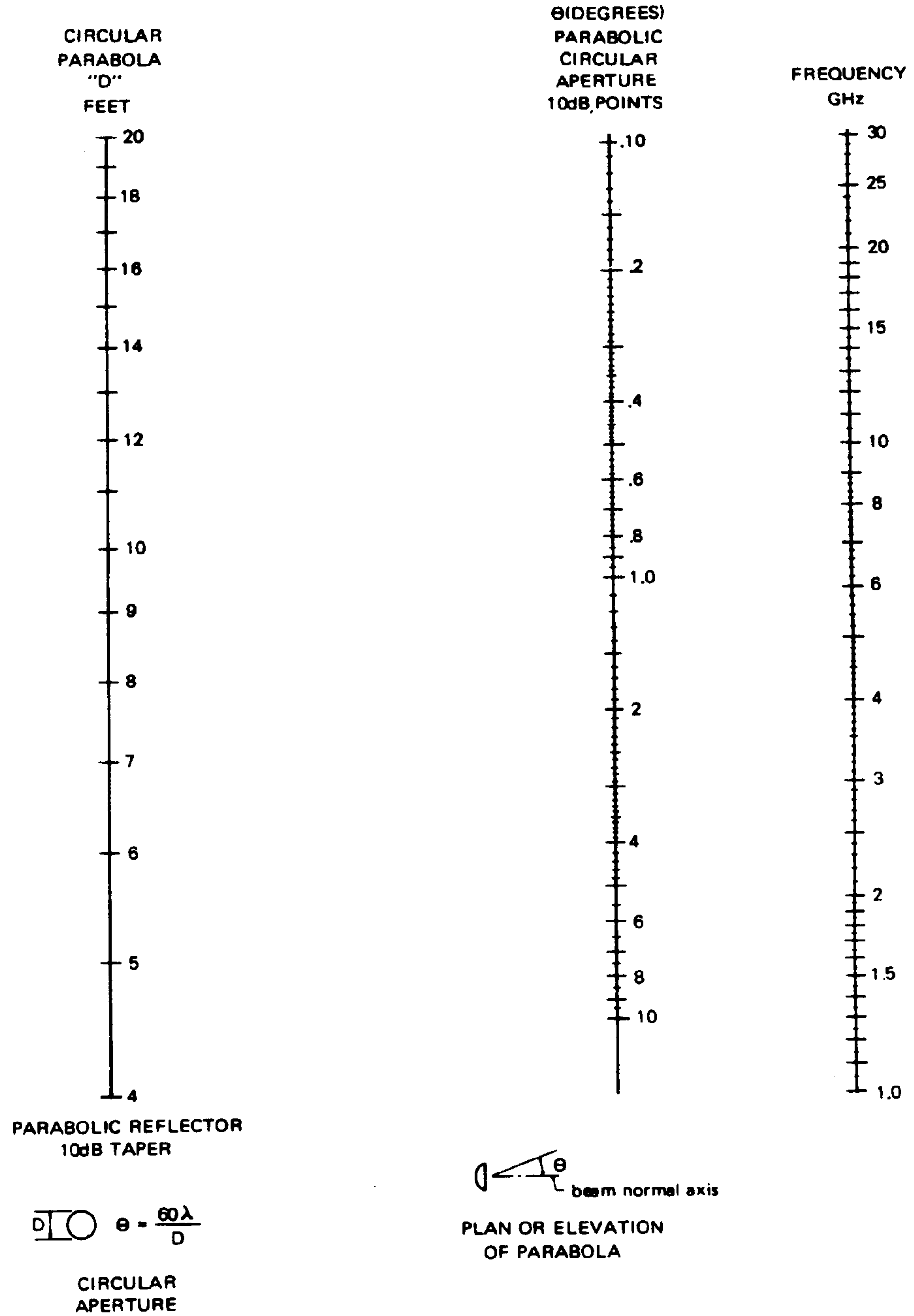
NOTE:
For the rotation of the reflector about its center an angle, δ, the deflected beam angle Θ, may vary from δ to 2δ in accordance with the antenna system geometery.

REFERENCE:
3 dB BEAMWIDTH, $2\Theta_{HP} = \frac{51\lambda}{W \text{ or } H}$

**NOMOGRAM— DEFLECTION ANGLE Θ
AT 10dB POINTS FOR RECTANGULAR APERTURE
(FLAT FACE REFLECTOR)**



NOMINAL BEAM WIDTH, 3 dB POINTS
TYPICAL PARABOLIC REFLECTOR



REFERENCE:
3 dB BEAM WIDTH, $2\theta_{HP} = \frac{70\lambda}{D}$

NOMOGRAM—DEFLECTION ANGLE, θ, AT 10dB POINTS FOR CIRCULAR APERTURE (PARABOLIC SURFACE CONTOUR)

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