

Foundation Specifications for 9-Meter Earth Station Antennas



1.0 INTRODUCTION

1.1 This document specifies typical foundation characteristics, designs, requirements and dimensional specifications for the Kratos 9-Meter Earth Station Antenna.

2.0 FOUNDATION LOADING CHARACTERISTICS

2.1 Foundation loads are applied to the three foundation pads as shown in Figure 1. Positive applied forces are in the direction of the X, Y, and Z coordinate axes.

2.2 Varying load conditions are dependent upon incident angle of the wind and elevation/azimuth angles of the antenna. Foundation loading moment for various elevation/azimuth versus wind conditions are listed in Table 1.

3.0 ANCHOR BOLT REQUIREMENTS

3.1 Typical anchor bolt installation configurations and dimensions are shown in Figures 2, 3 and 4.

3.2 Kratos type 201680 Anchor Bolt Kit includes anchor bolts, shear caps, anchor plates and required mounting hardware as shown in Figures 2, 3 and 4.

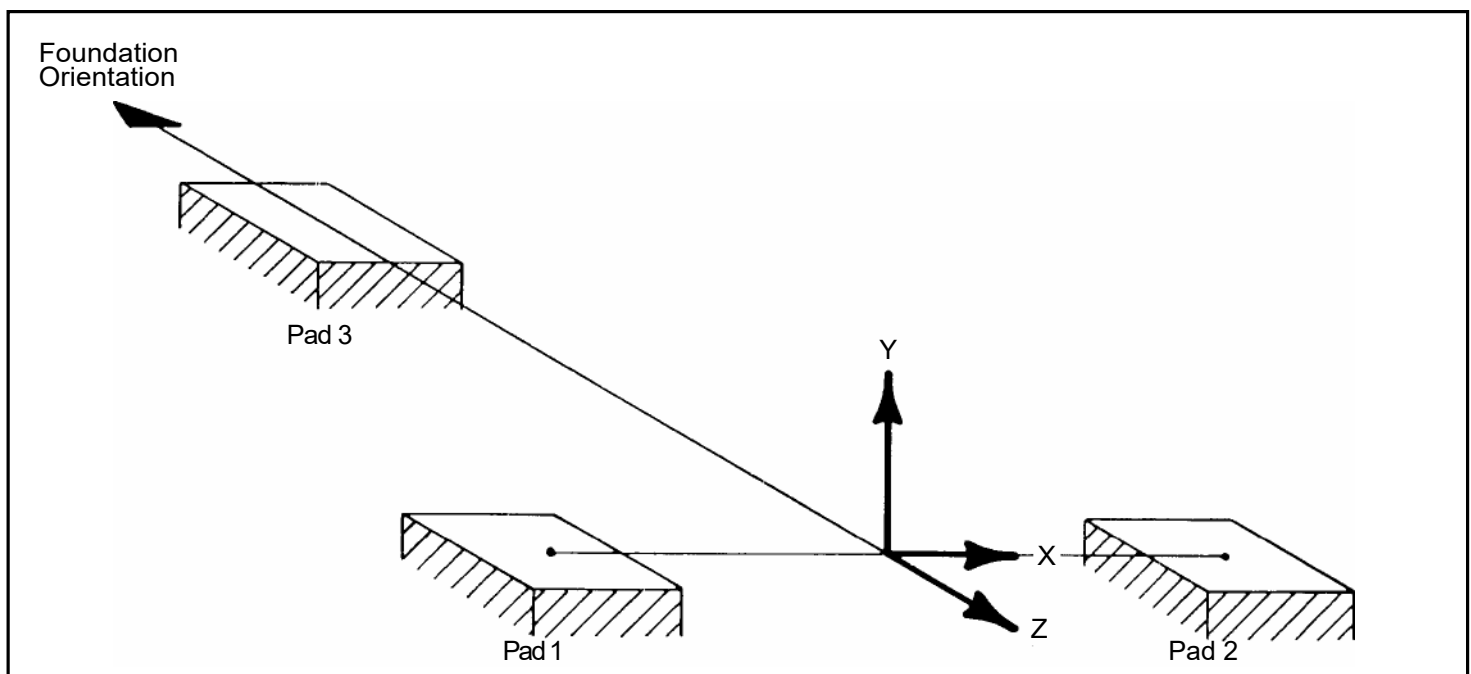
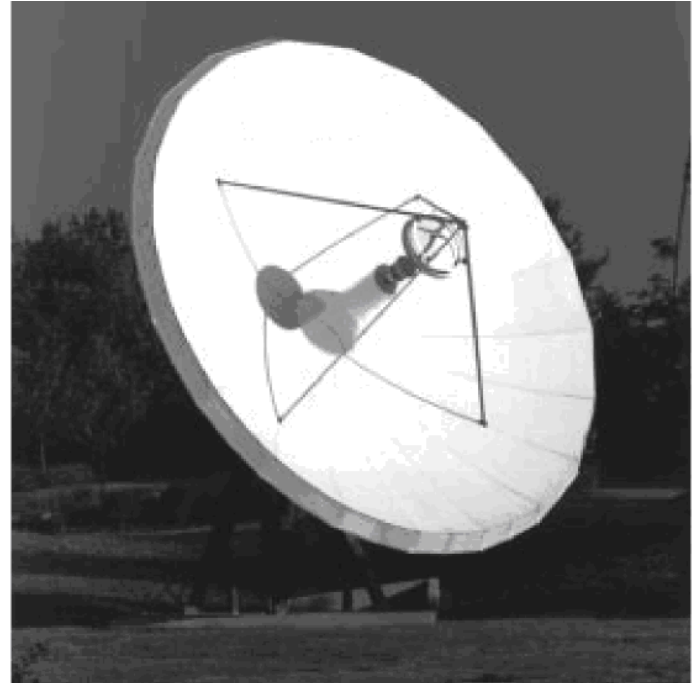


Figure 1

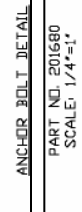
EL = 0°		FOUNDATION LOADING (1000 lbs)												
Speed (mph)	Wind Angle (α)	FDN Pad No.	AZ = 0°			AZ = -60°			AZ = +60°			AZ = +90°		
			X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z
125	0°	1	-13.3	-31.3	20.7	LOAD CASES FOR SPECIFIED AZIMUTH ANGLES DO NOT REPRESENT 'WORST CASE' CONDITIONS AND THEREFORE HAVE NOT BEEN CALCULATED								
		2	14.1	-33.1	22.8									
		3	-0.1	57.3	-3.4									
125	60°	1	-14.0	-32.6	17.3	9.0	20.6	-20.9	-23.1	-53.7	32.7	-18.6	-43.3	25.8
		2	11.0	-26.0	21.9	23.1	-54.1	42.3	-12.2	27.7	-16.4	-20.4	46.8	-29.6
		3	0.4	51.6	-2.5	-1.6	26.4	-0.8	2.2	19.1	0.3	2.3	-10.4	1.2
125	-60°	1	-10.9	-25.9	22.5	12.1	27.5	-15.4	-23.2	-54.4	43.3	-20.4	-48.0	39.0
		2	14.0	-32.8	17.8	23.2	-54.0	33.8	-8.8	20.3	-19.9	-18.3	42.2	-35.2
		3	-0.5	51.7	-3.4	-2.3	19.3	-2.3	1.6	27.1	-2.8	2.0	-1.1	-1.3
125	135°	1	1.6	3.0	8.9	-10.3	-24.5	28.8	11.8	26.7	-7.7	12.7	28.8	-9.5
		2	-10.6	24.6	-27.8	-11.0	25.6	-28.3	0.9	-1.9	-8.2	7.2	-16.7	2.2
		3	0.6	-34.7	3.3	3.6	-8.2	-1.1	-3.3	-31.7	0.8	-4.4	-18.9	-1.1
125	180°	1	9.3	21.3	-15.2	LOAD CASES FOR SPECIFIED AZIMUTH ANGLES DO NOT REPRESENT 'WORST CASE' CONDITIONS AND THEREFORE HAVE NOT BEEN CALCULATED.								
		2	-9.6	21.9	-15.3									
		3	0.0	-50.3	5.6									
125	-135°	1	10.7	24.8	-28.8	-0.6	-1.3	-10.5	11.3	26.1	-30.7	6.7	15.6	-23.2
		2	-1.6	3.0	8.0	-12.1	27.2	-10.0	10.1	-24.1	26.7	12.5	-29.8	30.5
		3	-0.7	-34.9	5.2	3.3	-33.0	5.5	-3.7	-9.0	3.4	-3.6	7.3	1.1

EL=30°		FOUNDATION LOADING (1000 lbs)												
Speed (mph)	Wind Angle (α)	FDN PadNo.	AZ = 0°			AZ = -60°			AZ = +60°			AZ = +90°		
			X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z
125	60°	1	-10.4	-24.3	12.3	7.9	18.3	-18.0	-18.4	-42.9	25.8	-15.2	-35.7	20.9
		2	9.7	-23.1	19.4	18.3	-43.0	33.9	-8.6	19.5	-11.1	-15.6	35.7	-22.4
		3	-1.8	23.6	0.6	0.4	0.0	2.4	-2.1	-1.2	-0.7	-1.3	-24.5	-0.9
125	-60°	1	-9.7	-23.1	19.6	8.6	19.4	-10.3	-18.3	-43.2	34.7	-15.6	-36.8	30.3
		2	10.4	-24.5	12.7	18.5	-43.1	26.7	-7.8	18.0	-17.1	-15.0	34.6	-28.9
		3	1.7	22.8	-0.2	2.1	-1.0	-2.5	-0.5	0.6	0.7	-1.6	-22.3	1.0
125	135°	1	2.2	4.6	4.3	-12.2	-28.8	28.0	14.3	32.6	-15.5	15.3	34.7	-17.3
		2	-12.8	29.6	-27.9	-13.5	31.3	-29.4	1.1	-2.5	-4.4	8.7	-20.3	8.1
		3	3.7	-37.6	7.7	8.5	-5.9	-0.6	-5.0	-33.5	6.1	-8.1	-17.7	2.3
125	-135°	1	12.8	29.7	-28.6	-0.9	-2.1	-6.0	13.7	31.6	-30.9	8.3	19.2	-22.2
		2	-2.2	4.5	3.7	-14.5	33.0	-17.1	12.0	-28.6	26.5	15.1	-35.8	31.4
		3	-3.8	-37.7	9.0	5.0	-34.4	9.2	-8.5	-6.4	2.4	-7.5	13.4	-2.4

EL = 60°		FOUNDATION LOADING (1000 lbs)												
Speed (mph)	Wind Angle (α)	FDN Pad No.	AZ = 0°			AZ = -60°			AZ = +60°			AZ = +90°		
			X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z
125	±60°	1	-5.2	-12.4	8.2	3.9	8.9	-6.7	-9.1	-21.6	15.1	-7.5	-18.0	12.5
		2	5.2	-12.5	8.3	9.1	-21.6	15.1	-3.9	8.8	-6.7	-7.5	17.1	-12.6
		3	0.1	-12.7	4.0	4.8	-24.9	1.9	-4.9	-24.7	1.9	-5.6	-36.5	0.1
125	120°	1	6.8	15.	-10.9	-6.3	-14.9	10.7	13.0	29.9	-21.5	11.1	25.4	-18.5
		2	-7.2	4	-11.8	-13.0	29.8	-21.8	5.8	-13.9	9.7	11.0	-25.8	18.1
		3	0.1	16.	10.2	8.3	-18.2	5.0	-8.1	-19.1	5.3	-9.5	-2.6	0.1
125	-120°	1	7.2	16.	-11.9	-5.8	-13.8	9.6	13.0	29.8	-21.8	10.8	24.7	-18.3
		2	-6.8	5	-10.8	-13.0	29.9	-21.5	6.3	-15.0	10.7	11.2	-26.5	18.7
		3	-0.2	15.	10.2	8.1	-19.3	5.4	-8.3	-18.0	5.0	-9.5	-1.2	-0.2

EL = 90°		FOUNDATION LOADING (1000 lbs)												
Speed (mph)	Wind Angle (α)	FDN Pad No.	AZ = 0°			AZ = -60°			AZ = +60°			AZ = +90°		
			X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z
125	±90°	1	-6.9	-16.4	11.5	-7.5	-17.7	11.8	-0.5	-1.2	1.6	4.5	10.0	-6.8
		2	-6.9	15.7	-11.7	0.3	-1.2	-0.2	-6.4	14.9	-9.6	-4.2	9.5	-6.5
		3	6.7	-3.3	0.1	3.6	14.8	-5.5	3.4	-13.6	6.0	-0.3	-23.3	6.2
125	-90°	1	6.9	15.7	-11.8	7.2	16.4	-11.6	-1.3	-3.0	1.5	-4.4	-10.6	6.4
		2	7.0	-16.6	11.5	-0.5	0.7	-0.2	8.2	-19.1	13.7	4.6	-11.1	6.9
		3	-6.8	-3.2	0.2	-3.2	-21.2	5.7	-3.3	22.3	-5.0	-0.1	17.9	-6.2

Table 1



**Foundation Layout - Slab
9-Meter Earth Station Antenna
Figure 2**

General Notes – Figure 2

1. Remove all burrs and sharp edges.
2. Dimensions apply before plating.
3. Interpret drawing per ANSI Y1 4.5M-1 982.
4. Dimensions are shown in feet and inches. Dimensions in brackets [] are in millimeters.
5. A tolerance of $\pm 1/8"$ [3] applies to all anchor bolt layout dimensions.
6. Level all shear caps individually and to within $\pm 1/4"$ [6] of each other.

7. Foundation Notes:

- A) This foundation is a typical design only. Certification of its suitability for a particular installation by a professional engineer is required prior to its use for actual fabrication.
- B) Contractor shall field verify all dimensions locating existing construction before fabrication of new construction begins.
- C) Concrete and related work shall be mixed, placed and cured in accordance with 'Building Code Requirements for Reinforced Concrete' ACI 318-89 (Rev. 88) and 'Specifications for Structural Concrete' ACI 301-84 (Rev. 88) publication SP-1 5 (88).
- D) Concrete for foundations shall develop a compressive strength of at least 3000 psi [211 kgf/cm² in 28 days with a maximum slump of 3" [76] at time of placing.
- E) Reinforcing bars shall conform to ASTM A 615 [S1] grade 60 deformed type $F_y = 60000$ psi [4219 kgf/cm²].
- F) Unless otherwise noted, concrete cover of reinforcing bars shall conform to minimum requirements of ACI 318-89 (Rev. 88).
- G) Fabrication of reinforcing steel shall be in accordance with 'Manual of Standard Practice for Detailing Reinforced Concrete Structures' ACI 315-80 (Rev. 86).
- H) Provide $3/4" \times 45^\circ$ [19 x 45°] chamfer on all exposed concrete edges.
- J) Foundations have been designed to rest on undisturbed soil (per EIA-41 1-A and RS-222-D) with a minimum allowable net vertical bearing capacity of 2000 psf [9770 kgf/m²]. If undesirable soil conditions are encountered, the engineer shall be notified.
- K) Backfills shall be suitable excavated material or other suitable material compacted in 6" lifts to 90% of maximum density as determined by ASTM D1 557.
- L) If this foundation is to be located in an area where annual frost penetration depth exceeds 21" [533], the local building code specifying a minimum required foundation depth should be consulted.

8. Grounding Electrode System Notices:

The grounding system shown represents the minimum requirements to achieve satisfactory grounding. Actual site conditions and soil resistivity levels will determine final grounding system design to comply with the following:

- A) All ground ring, ground rod and antenna structure connections to be ERICO® products, Inc. Calweld® exothermic type welded electrical connections or equivalent.
- B) Ground rods shall be driven to a depth below permanent moisture level (minimum depth shown) as dictated by geographical location.
- C) The antenna structure shall be connected to a grounding electrode system consisting of a number of interconnected ground rods. The system shall meet the requirements of the Underwriters' Laboratories Publication No. UL96A for Lightning protection.
- D) The grounding electrode system to earth resistance shall not exceed 10 Ohms, measured with a Biddle 3 terminal device or equivalent. The grounded conductor (neutral) supplied to all ac equipment on the antenna structure should be disconnected before taking measurement.
- E) Actual site conditions may require longer ground rods, additional ground rods and/or land fill additives to reduce soil resistivity levels.
- F) Avoid sharp bends when routing grounding wire. Grounding wires to antenna structure to be run as short and straight as possible.
- G) Final grade directly above grounding electrode system to be water permeable.

9. Power/IFL Conduit Notes:

- A) Electrical power - Drawing depicts suggested location for electrical power conduit to antenna. Size, type and depth to bury conduit to be determined by customer in compliance with local codes. Direction to route conduit to be determined by the relative location of communications building/shelter. Power conduit to extend 6" (minimum) above surface of foundation slab. Open ends of conduit to be sealed to prevent moisture and foreign particle contamination.

Customer to provide main load center assembly and over-current protection devices for electrical equipment. Mounting location of load center to be determined by customer in accordance with local codes.
- B) IFL cable - Drawing depicts suggested location for IFL conduit. Conduit required only if no other means for routing IFL cables is provided. Size, type and depth to bury conduit to be determined by customer in compliance with local codes. Direction to route conduit to be determined by the relative location of communications building/shelter. IFL conduit to extend 36" (minimum) above surface of foundation slab. All bends to be large radius with a minimum of (2) 90° bends per run. Open ends of conduit to be sealed to prevent moisture and foreign particle contamination.

General Notes – Figure 3

1. Remove all burrs and sharp edges.
2. Dimensions apply before plating.
3. Interpret drawing per ANSI Y1 4.5M-1 982.
4. Dimensions are shown in feet and inches. Dimensions in brackets [] are in millimeters.
5. A tolerance of $\pm 1/8"$ [3] applies to all anchor bolt layout dimensions.
6. Level all shear caps individually and to within $\pm 1/4"$ [6] of each other.

7. Foundation Notes:

- A) This foundation is a typical design only. Certification of its suitability for a particular installation by a professional engineer is required prior to its use for actual fabrication.
- B) Contractor shall field verify all dimensions locating existing construction before fabrication of new construction begins.
- C) Concrete and related work shall be mixed, placed and cured in accordance with 'Building Code Requirements for Reinforced Concrete' ACI 318-89 (Rev. 88) and 'Specifications for Structural Concrete' ACI 301-84 (Rev. 88) publication SP-1 5 (88).
- D) Concrete for foundations shall develop a compressive strength of at least 3000 psi [211 kgf/cm² in 28 days with a maximum slump of 3" [76] at time of placing.
- E) Reinforcing bars shall conform to ASTM A 615 [S1] grade 60 deformed type $F_y = 60000$ psi [4219 kgf/cm²].
- F) Unless otherwise noted, concrete cover of reinforcing bars shall conform to minimum requirements of ACI 318-89 (Rev. 88).
- G) Fabrication of reinforcing steel shall be in accordance with 'Manual of Standard Practice for Detailing Reinforcing Concrete Structures' ACI 315-80 (Rev. 86).
- H) Provide $3/4" \times 45^\circ$ [19 x 45°] chamfer on all exposed concrete edges.
- J) Foundations have been designed to rest on undisturbed soil (per EIA-41 1-A and RS-222-D) with a minimum allowable net vertical bearing capacity of 2000 psf [9770 kgf/m²]. If undesirable soil conditions are encountered, the engineer shall be notified.
- K) Backfills shall be suitable excavated material or other suitable material compacted in 6" lifts to 90% of maximum density as determined by ASTM D1 557.

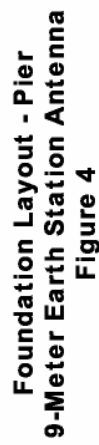
8. Grounding Electrode System Notices:

The grounding system shown represents the minimum requirements to achieve satisfactory grounding. Actual site conditions and soil resistivity levels will determine final grounding system design to comply with the following:

- A) All ground ring, ground rod and antenna structure connections to be ERICO® products, Inc. Calweld® exothermic type welded electrical connections or equivalent.
- B) Ground rods shall be driven to a depth below permanent moisture level (minimum depth shown) as dictated by geographical location.
- C) The antenna structure shall be connected to a grounding electrode system consisting of a number of interconnected ground rods. The system shall meet the requirements of the Underwriters' Laboratories Publication No. UL96A for Lightning protection.
- D) The grounding electrode system to earth resistance shall not exceed 10 Ohms, measured with a Biddle 3 terminal device or equivalent. The grounded conductor (neutral) supplied to all ac equipment on the antenna structure should be disconnected before taking measurement.
- E) Actual site conditions may require longer ground rods, additional ground rods and/or land fill additives to reduce soil resistivity levels.
- F) Avoid sharp bends when routing grounding wire. Grounding wires to antenna structure to be run as short and straight as possible.
- G) Final grade directly above grounding electrode system to be water permeable.

9. Power/IFL Conduit Notes:

- A) Electrical power - Size, type and depth to bury conduit to be determined by customer in compliance with local codes. Direction to route conduit to be determined by the relative location of communications building/shelter. Open ends of conduit to be sealed to prevent moisture and foreign particle contamination. Customer to provide main load center assembly and over-current protection devices for electrical equipment. Mounting location of load center to be determined by customer in accordance with local codes.
- B) IFL cable - Conduit required only if no other means for routing IFL cables is provided. Size, type and depth to bury conduit to be determined by customer in compliance with local codes. Direction to route conduit to be determined by the relative location of communications building/shelter. All bends to be large radius with a minimum of (2) 90° bends per run. Open ends of conduit to be sealed to prevent moisture and foreign particle contamination.



General Notes - Figure 4

1. Remove all burrs and sharp edges.
2. Dimensions apply before plating.
3. Interpret drawing per ANSI Y1 4.5M-1 982.
4. Dimensions are shown in feet and inches. Dimensions in brackets [] are in millimeters.
5. A tolerance of $\pm 1/8"$ [3] applies to all anchor bolt layout dimensions.
6. Level all shear caps individually and to within $\pm 1/4"$ [6] of each other.

7. Foundation Notes:

- A) This foundation is a typical design only. Certification of its suitability for a particular installation by a professional engineer is required prior to its use for actual fabrication.
- B) Contractor shall field verify all dimensions locating existing construction before fabrication of new construction begins.
- C) Concrete and related work shall be mixed, placed and cured in accordance with 'Building Code Requirements for Reinforced Concrete' ACI 318-89 (Rev. 88) and 'Specifications for Structural Concrete' ACI 301-84 (Rev. 88) publication SP-1 5 (88).
- D) Concrete for foundations shall develop a compressive strength of at least 3000 psf [211 kgf/cm² in 28 days with a maximum slump of 3" [76] at time of placing.
- E) Reinforcing bars shall conform to ASTM A 615 [S1] grade 60 deformed type $F_y = 60000$ psi [4219 kgf/cm²].
- F) Unless otherwise noted, concrete cover of reinforcing bars shall conform to minimum requirements of ACI 318-89 (Rev. 88).
- G) Fabrication of reinforcing steel shall be in accordance with 'Manual of Standard Practice for Detailing Reinforced Concrete Structures' ACI 315-80 (Rev. 86).
- H) Provide $3/4" \times 45^\circ$ [19 x 45°] chamfer on all exposed concrete edges.
- J) Piers are to be designed by a registered professional engineer for depth, type and reinforcement for the following loads:

Pier 1	54.4 (Down)	-32.6 (Up)
Pier 2	54.1 (Down)	-35.7 (Up)
Pier 3	50.3 (Down)	-57.3 (Up)
- K) Backfills shall be suitable excavated material or other suitable material compacted in 6" lifts to 90% of maximum density as determined by ASTM D1 557.
- L) The excavation and base flare are to be made with an auger and the caissons are to be cast against undisturbed soil.
- M) Forming is required for the grade beams and the footings above ground.
- N) This alternate foundation plan may be required in lieu of the footing foundation if space is limited, the soils may settle excessively or the soils are active and may heave excessively.

8. Grounding Electrode System Notes:

The grounding system shown represents the minimum requirements to achieve satisfactory grounding. Actual site conditions and soil resistivity levels will determine final grounding system design to comply with the following:

- A) All ground ring, ground rod and antenna structure connections to be ERICO® products, Inc. Calweld® exothermic type welded electrical connections or equivalent.
- B) Ground rods shall be driven to a depth below permanent moisture level (minimum depth shown) as dictated by geographical location.
- C) The antenna structure shall be connected to a grounding electrode system consisting of a number of interconnected ground rods. The system shall meet the requirements of the Underwriters' Laboratories Publication No. UL96A for Lightning protection.
- D) The grounding electrode system to earth resistance shall not exceed 10 Ohms, measured with a Biddle 3 terminal device or equivalent. The grounded conductor (neutral) supplied to all ac equipment on the antenna structure should be disconnected before taking measurement.
- E) Actual site conditions may require longer ground rods, additional ground rods and/or land fill additives to reduce soil resistivity levels.
- F) Avoid sharp bends when routing grounding wire. Grounding wires to antenna structure to be run as short and straight as possible.
- G) Final grade directly above grounding electrode system to be water permeable.

9. Power/IFL Conduit Notes:

- A) Electrical power - Size, type and depth to bury conduit to be determined by customer in compliance with local codes. Direction to route conduit to be determined by the relative location of communications building/shelter. Open ends of conduit to be sealed to prevent moisture and foreign particle contamination.
Customer to provide main load center assembly and over-current protection devices for electrical equipment. Mounting location of load center to be determined by customer in accordance with local codes.
- B) IFL cable - Conduit required only if no other means for routing IFL cables is provided. Size, type and depth to bury conduit to be determined by customer in compliance with local codes. Direction to route conduit to be determined by the relative location of communications building/shelter. All bends to be large radius with a minimum of (2) 90° bends per run. Open ends of conduit to be sealed to prevent moisture and foreign particle contamination.

4.0 FOUNDATION DESIGNS

4.1 The selected foundation for a particular site is dependent upon local conditions. Soil borings and foundation analysis should be performed by a qualified civil engineer.

4.2 Typical designs for slab and pier type foundations are shown in Figures 2, 3 and 4. Copies of these designs on D- size (22" x 33") sheets are available from Kratos on request. Refer to drawing numbers 240000 (slab type), 240007 (pier type) and 240006 (buried slab type).

5.0 FOUNDATION ORIENTATION

5.1 Proper foundation orientation is required to obtain the

desired orbital arc coverage from a particular site location.

The required azimuth and elevation angles of the antenna, relative to the mount must be determined to establish the appropriate foundation orientation. A specific foundation orientation requirement may be requested with the antenna as part of the installation package.

6.0 ANTENNA GEOMETRY

6.1 Basic dimensional characteristics and azimuth adjustment range capabilities are shown in Figure 5.

6.2 Figure 6 illustrates varying dimensions from ground reference of selected antenna points as the elevation angle fluctuates from 0 to 90°.

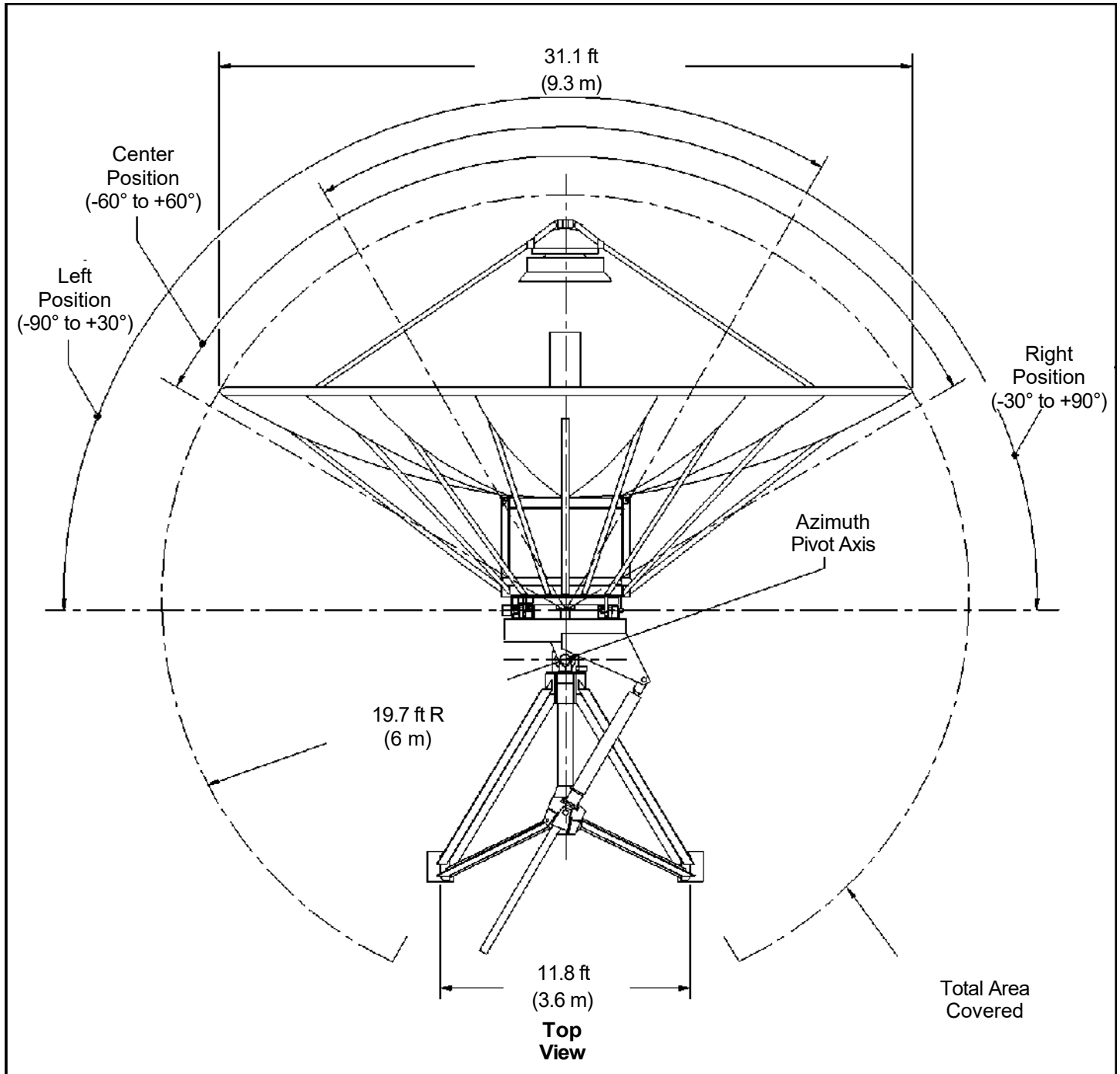


Figure 5
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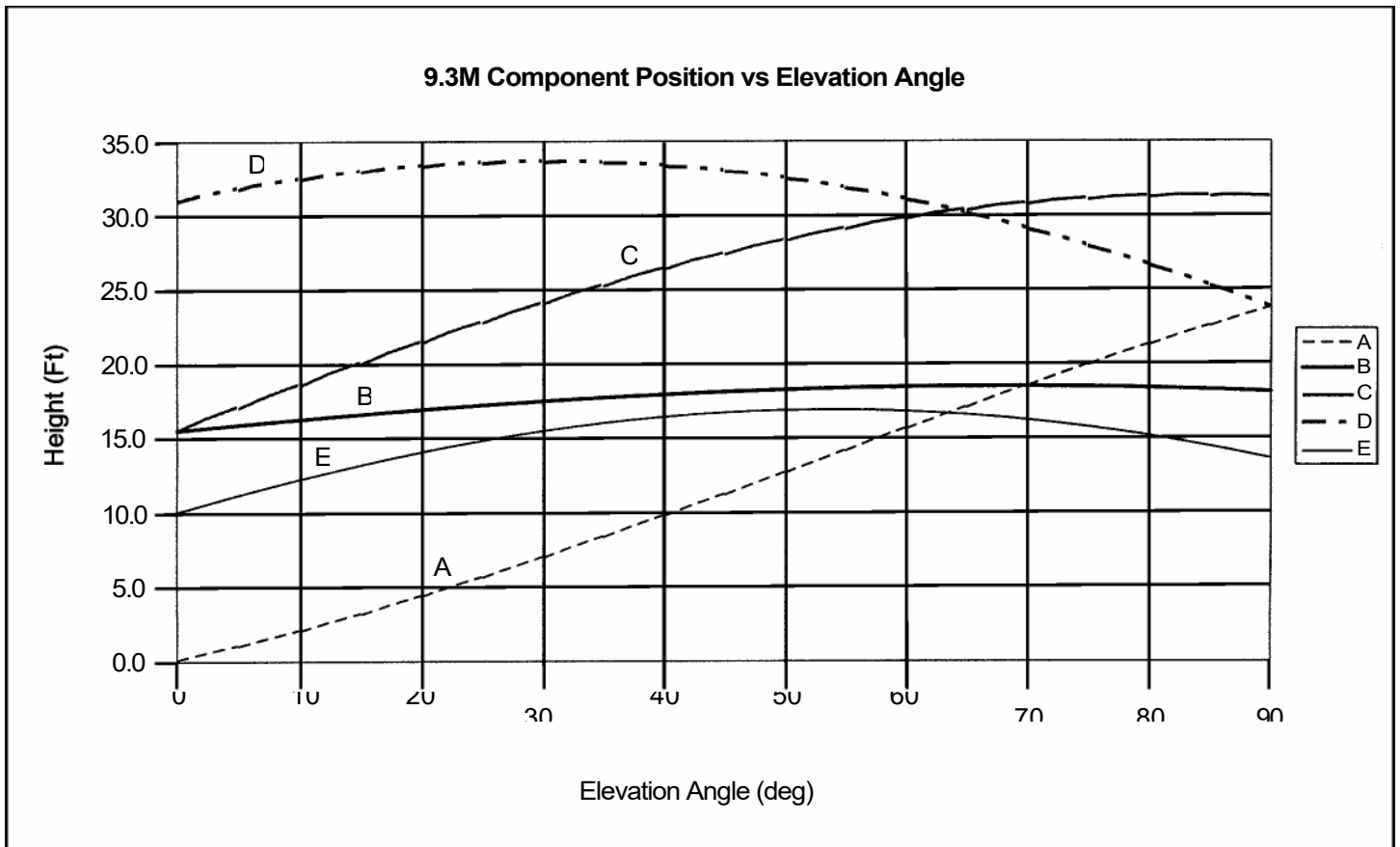
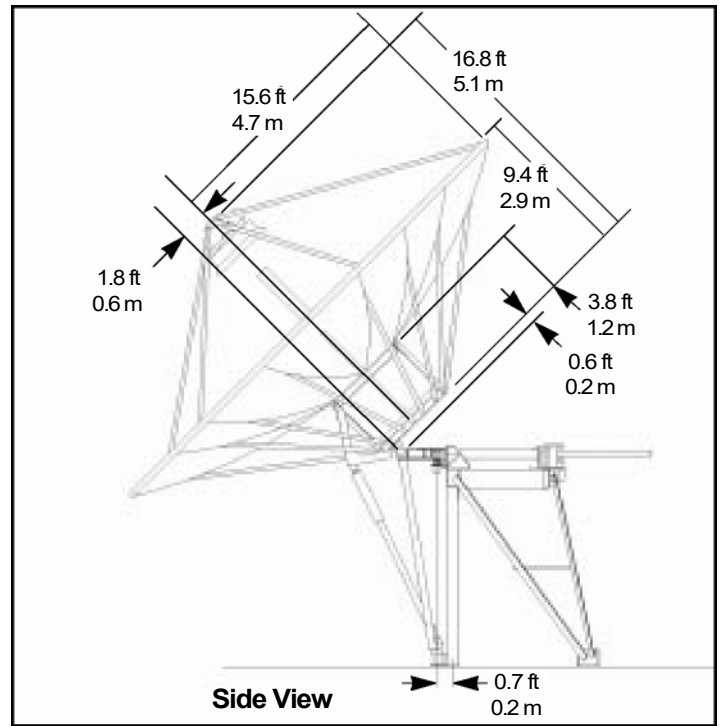
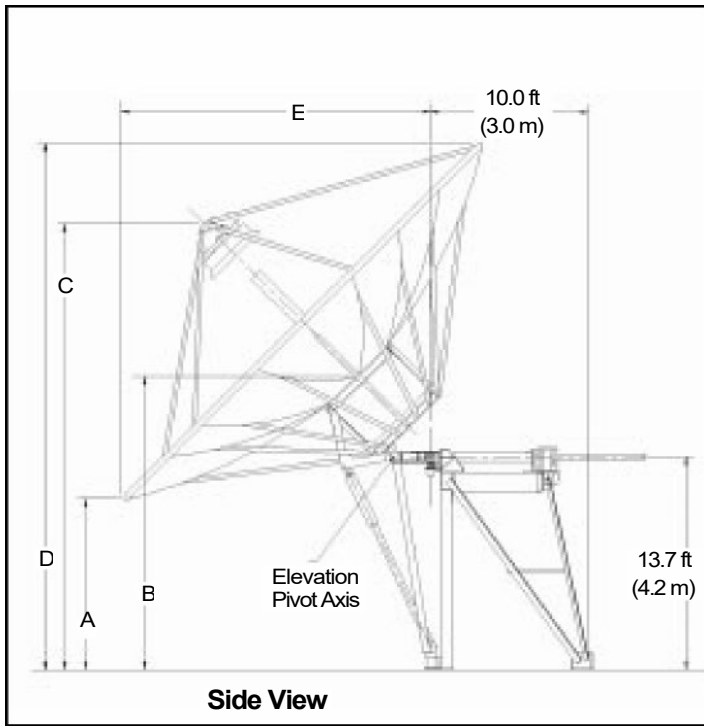


Figure 6

ANTENNA POINTING CALCULATIONS

This section contains the formulas for determining the pointing capabilities of the 9-meter earth station antenna.

Formulas for calculating true azimuth (AZ), true elevation (EL), relative angle between true azimuth and mount pointing angle (dAZ) and strut lengths of the earth station are given below:

Given the earth station latitude, longitude, azimuth setting of mount (AZm) and satellite longitude (over the equator), the following calculations can be made:

For earth stations north of the equator:

$$AZ = 180^\circ + \arctan(\tan \theta / \sin \alpha)$$

For earth stations south of the equator:

$$AZ = 360^\circ - \arctan(\tan \theta / \sin \alpha)$$

Where:

AZ = true azimuth to view satellite, in degrees East (clockwise) of True North.

α = earth station latitude in degrees.

θ = satellite longitude minus earth station longitude, in degrees.

NOTE: Earth station latitude values are positive for sites located north of the equator and negative for sites south of the equator. Longitude values are positive for earth station sites or satellite positions west of Greenwich and negative east of Greenwich.

$$dAZ = AZ - AZm$$

Where:

AZm = azimuth at which mount is set in degrees East (clockwise) of True North

dAZ = relative angle between true azimuth angle looking at satellite and mount pointing direction in degrees.

$$EL = 90^\circ - T - R$$

Where:

EL = true elevation angle to view satellite in degrees

R = $\arccos(\cos \theta \cos \alpha)$

T = $\arctan[\sin R / (6.6166 - \cos R)]$

Pin to pin length of elevation strut in inches:

$$\text{Equation (1): } XEL = \sqrt{26259.7740 - 14970.1377 [\cos (27.0362^\circ + EL)]}$$

For the -90° to +30° dAZ Range:

Pin to pin length of azimuth strut in inches:

$$\text{Equation (2): } LAZ = \sqrt{7571.2865 - 6181.928 [\cos (105^\circ + dAZ)]}$$

For the -60° to +60° dAZ Range:

Pin to pin length of azimuth strut in inches:

$$\text{Equation (3): } LAZ = \sqrt{7571.2865 - 6181.928 [\cos (75^\circ - dAZ)]}$$

For the -30° to +90° dAZ Range:

Pin to pin length of azimuth strut in inches:

$$\text{Equation (4): } LAZ = \sqrt{7571.2865 - 6181.928 [\cos (105^\circ - dAZ)]}$$