ANTENNA MASTS

Lewis Thompson, W5IFQ
7 JUL 2020

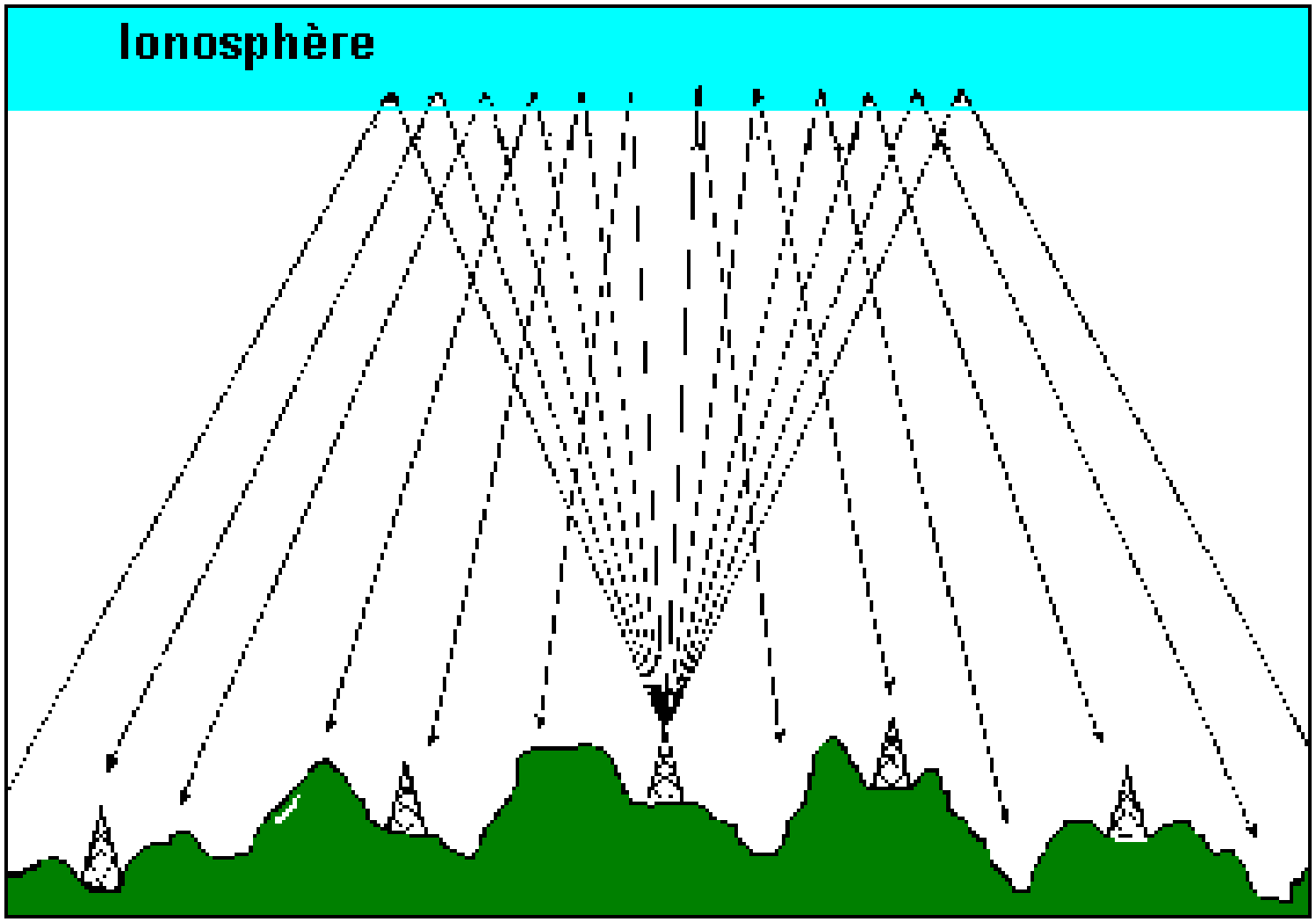
Purpose & Approach

- Purpose – to provide real-world antenna mast selection criteria.
- Approach - I am only considering masts and towers that I have personal experience installing and using.

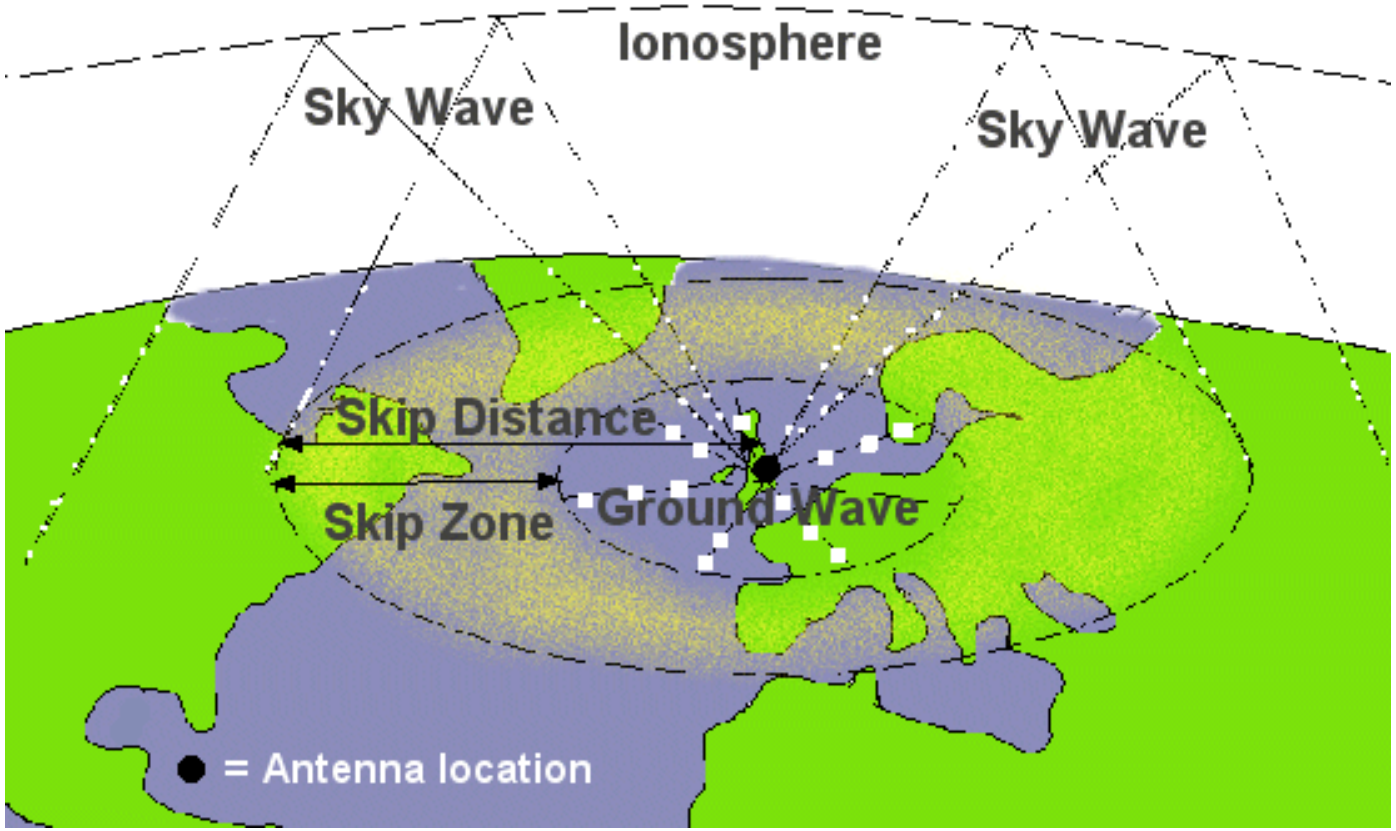
Optimum Antenna Height for Type of Communications

- Local - Near Vertical Incident Sky Wave (NVIS)
  - Must operate at or below local Critical Frequency
- Long-Range – Sky Wave with a skip zone
  - Must operate at or below Maximum Useable Frequency (MUF) for required range

NVIS Propagation



Long Distance Sky Wave



Wavelength Versus Frequency

- Once we know our operating frequency based on range, it is easier to talk about wavelengths rather than frequency.
- Wavelength = Speed of Light ÷ Frequency
- Or λ (ft.) = 983.6 ÷ f (MHz)

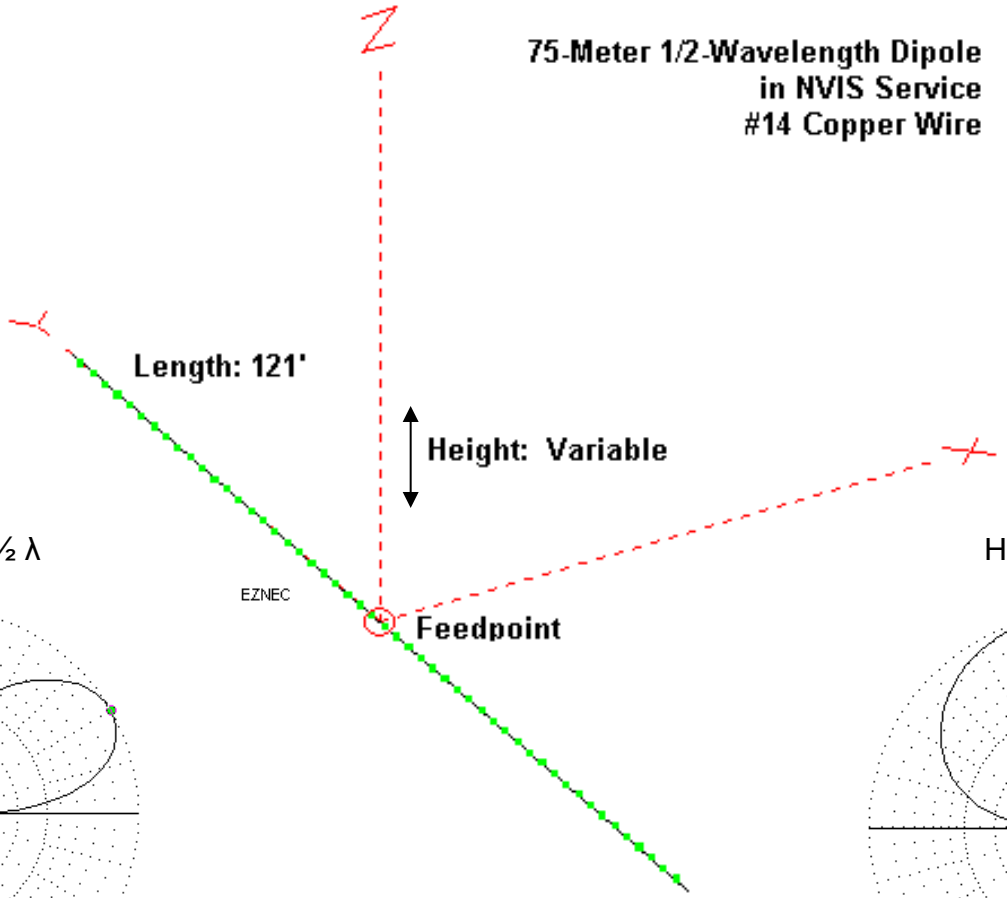
Frequency to Wavelength Chart

Frequency (kHz)		Wavelength (Meters)		Wavelength (Feet)		1/2 Wavelength (Feet)		1/4 Wavelength (Feet)		1/3 Wavelength (Feet)		1/10 Wavelength (Feet)	
2,194.00	2,495.00	136.7	120.2	448.6	394.5	224.3	197.2	112.2	98.6	149.5	131.5	44.9	39.4
2,505.00	2,850.00	119.8	105.3	392.9	345.3	196.5	172.7	98.2	86.3	131.0	115.1	39.3	34.5
3,155.00	3,400.00	95.1	88.2	312.0	289.5	156.0	144.7	78.0	72.4	104.0	96.5	31.2	28.9
4,000.00	4,063.00	75.0	73.8	246.1	242.2	123.0	121.1	61.5	60.6	82.0	80.7	24.6	24.2
4,438.00	4,650.00	67.6	64.5	221.8	211.7	110.9	105.8	55.4	52.9	73.9	70.6	22.2	21.2
4,750.00	4,995.00	63.2	60.1	207.2	197.0	103.6	98.5	51.8	49.3	69.1	65.7	20.7	19.7
5,005.00	5,450.00	59.9	55.0	196.7	180.6	98.3	90.3	49.2	45.1	65.6	60.2	19.7	18.1
5,730.00	5,950.00	52.4	50.4	171.8	165.4	85.9	82.7	42.9	41.4	57.3	55.1	17.2	16.5
6,765.00	7,000.00	44.3	42.9	145.5	140.6	72.7	70.3	36.4	35.2	48.5	46.9	14.5	14.1
7,300.00	8,195.00	41.1	36.6	134.8	120.1	67.4	60.1	33.7	30.0	44.9	40.0	13.5	12.0
9,040.00	9,500.00	33.2	31.6	108.9	103.6	54.4	51.8	27.2	25.9				
9,900.00	9,995.00	30.3	30.0	99.4	98.5	49.7	49.2	24.9	24.6				
10,150.00	11,175.00	29.6	26.8	97.0	88.1	48.5	44.0	24.2	22.0				
11,400.00	11,650.00	26.3	25.8	86.3	84.5	43.2	42.2	21.6	21.1				
12,050.00	12,230.00	24.9	24.5	81.7	80.5	40.8	40.2	20.4	20.1				
13,410.00	13,600.00	22.4	22.1	73.4	72.4	36.7	36.2	18.3	18.1				
13,800.00	14,000.00	21.7	21.4	71.3	70.3	35.7	35.2	17.8	17.6				
14,350.00	14,990.00	20.9	20.0	68.6	65.7	34.3	32.8	17.1	16.4				
15,600.00	16,360.00	19.2	18.3	63.1	60.2	31.5	30.1	15.8	15.0				
17,410.00	17,550.00	17.2	17.1	56.5	56.1	28.3	28.0	14.1	14.0				
18,030.00	18,068.00	16.6	16.6	54.6	54.5	27.3	27.2	13.6	13.6				
18,168.00	18,780.00	16.5	16.0	54.2	52.4	27.1	26.2	13.5	13.1				
18,900.00	19,660.00	15.9	15.3	52.1	50.1	26.0	25.0	13.0	12.5				
19,800.00	19,990.00	15.2	15.0	49.7	49.2	24.9	24.6	12.4	12.3				
20,010.00	21,000.00	15.0	14.3	49.2	46.9	24.6	23.4	12.3	11.7				
21,855.00	23,200.00	13.7	12.9	45.0	42.4	22.5	21.2	11.3	10.6				
23,350.00	24,890.00	12.8	12.1	42.2	39.5	21.1	19.8	10.5	9.9				
25,330.00	25,550.00	11.8	11.7	38.9	38.5	19.4	19.3	9.7	9.6				
26,480.00	28,000.00	11.3	10.7	37.2	35.2	18.6	17.6	9.3	8.8				
29,800.00	30,000.00	10.1	10.0	33.0	32.8	16.5	16.4	8.3	8.2				

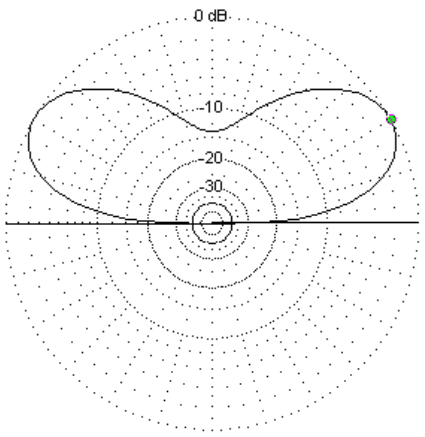
NVIS

Long-Range

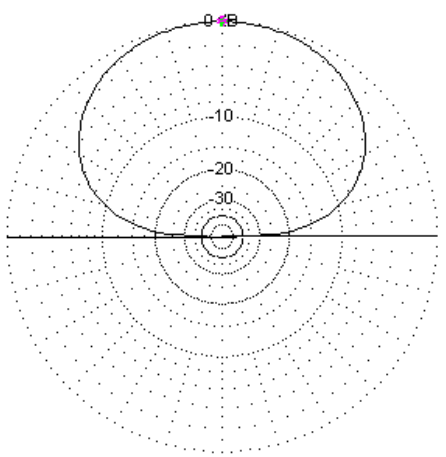
Dipole Directivity Pattern versus Height
(1/2 Wavelength Dipole)



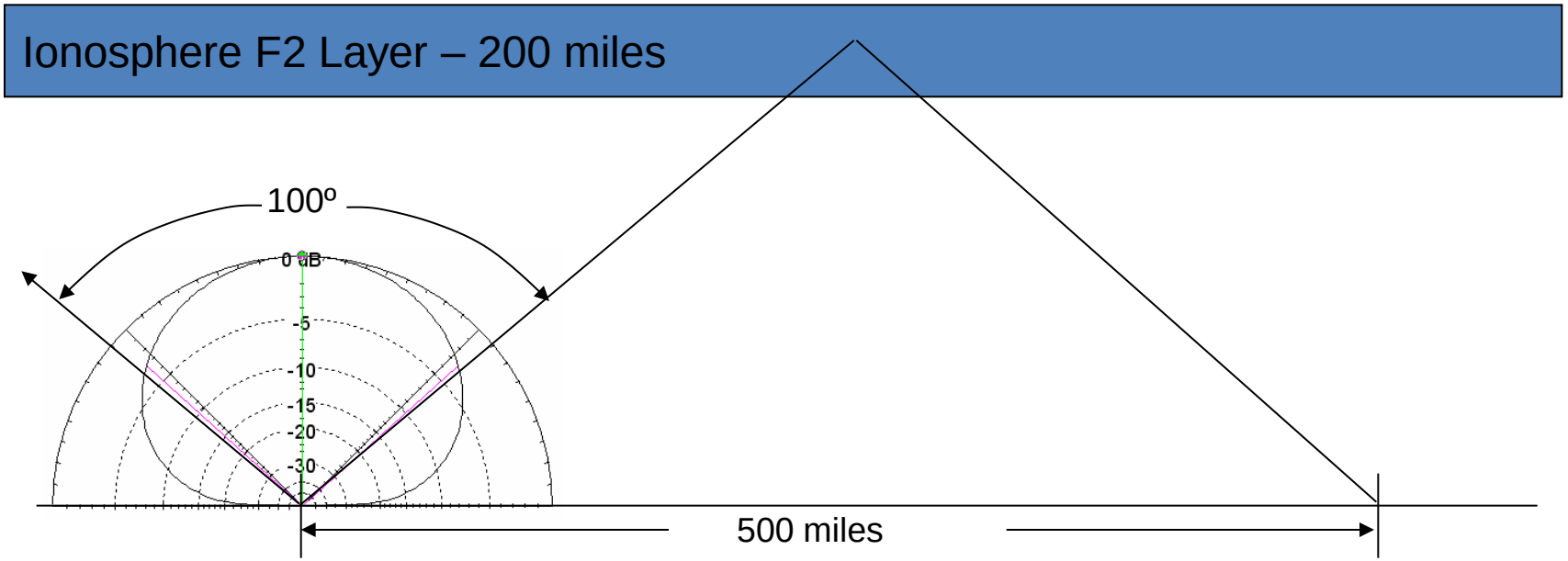
Height = ½ λ



Height = .15 λ

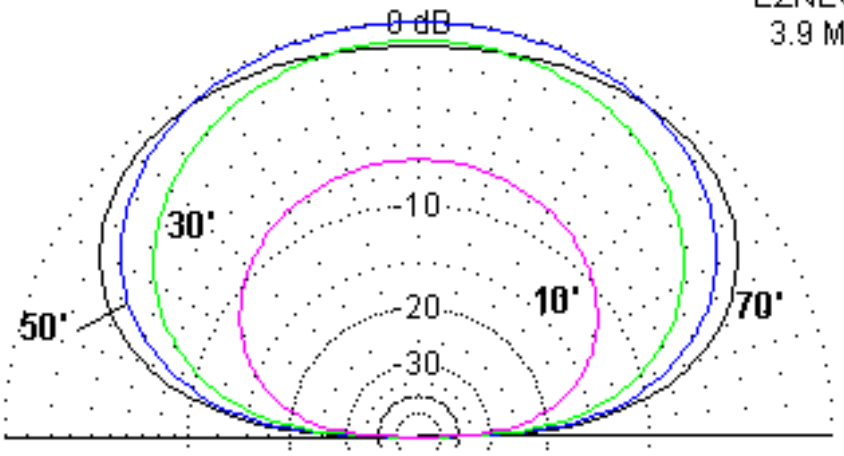


Required NVIS Antenna Pattern

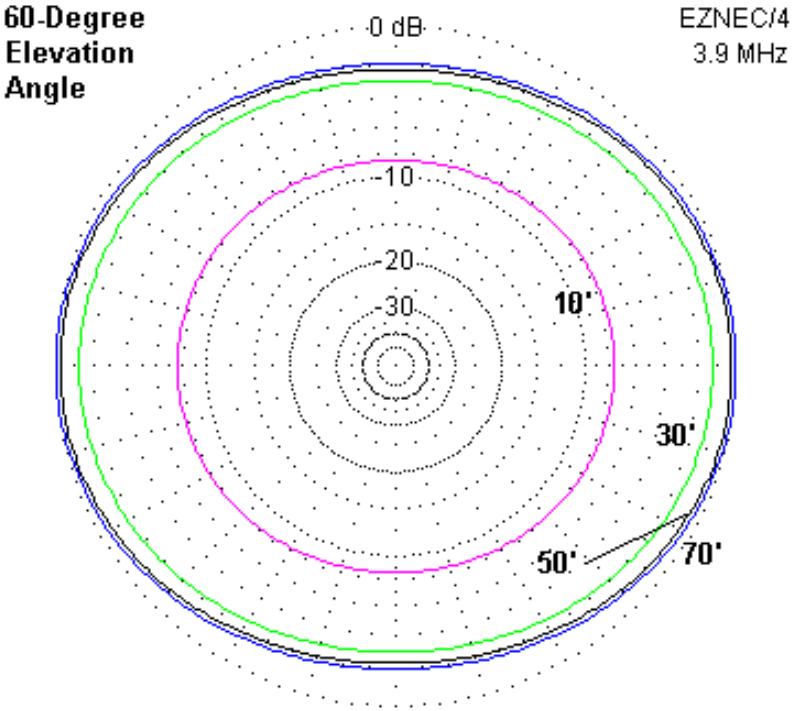


- Want to optimize take-off angles from 50º to 90º
- Elevation Beam width = 100º
- Centered on the vertical axis.

NVIS Dipole Patterns Versus Height



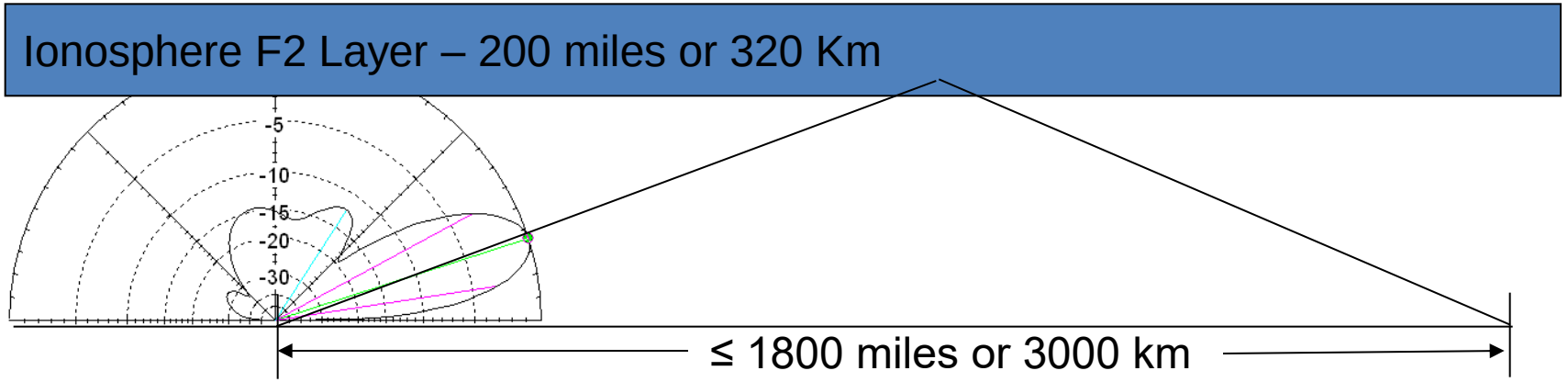
Elevation Patterns of a 75-Meter Dipole for NVIS Service at 10, 30, 50, and 70 Feet Above Average Soil



Azimuth Patterns of a 75-Meter Dipole for NVIS Service at 10, 30, 50, and 70 Feet Above Average Soil

70 ft. = 0.28λ
50 ft. = 0.19λ
30 ft. = 0.11λ

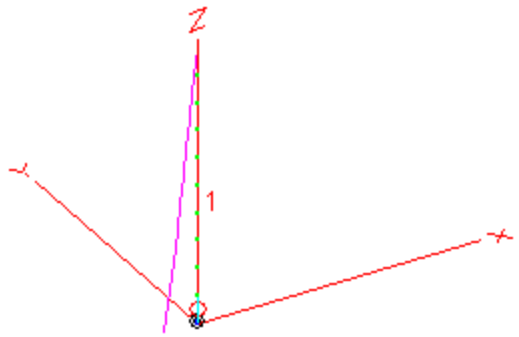
TYPICAL LONG-RANGE PROPAGATION



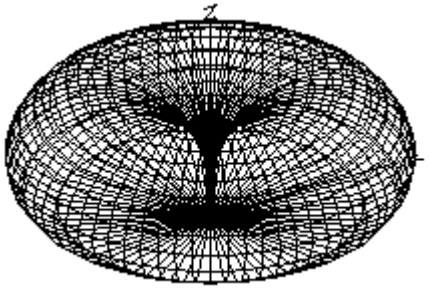
Both F2 & E layers propagation can be involved in multiple reflection circuits.

VERTICAL ANTENNAS

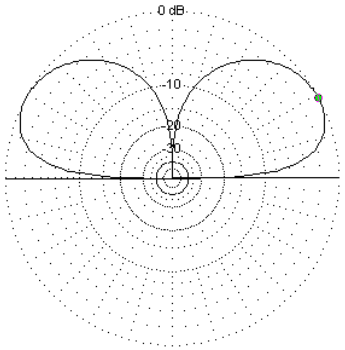
EZNEC



Height = 1.8 m (6 ft)

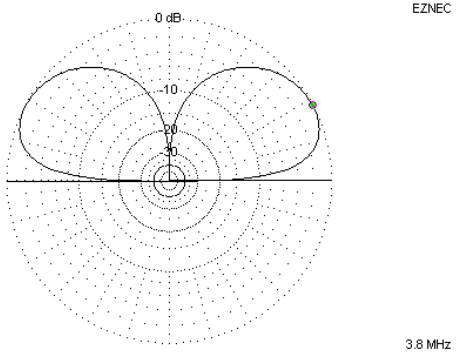


7 MHz



Elevation Plot		Cursor Elev	29.0 deg.
Azimuth Angle	0.0 deg.	Gain	0.29 dBi
Outer Ring	0.29dBi		0.0 dBmax
Slice Max Gain	0.29 dBi @ Elev Angle = 29.0 deg.		
Beamwidth	47.6 deg.; -3dB @ 9.8, 57.4 deg.		
Sidelobe Gain	0.29 dBi @ Elev Angle = 151.0 deg.		
Front/Sidelobe	0.0 dB		

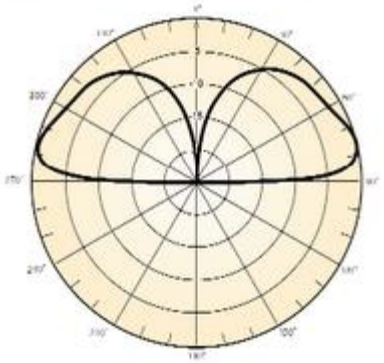
3.8 MHz



Elevation Plot		Cursor Elev	28.0 deg.
Azimuth Angle	0.0 deg.	Gain	0.92 dBi
Outer Ring	0.92dBi		0.0 dBmax
Slice Max Gain	0.92 dBi @ Elev Angle = 28.0 deg.		
Beamwidth	47.7 deg.; -3dB @ 8.9, 56.6 deg.		
Sidelobe Gain	0.92 dBi @ Elev Angle = 152.0 deg.		
Front/Sidelobe	0.0 dB		

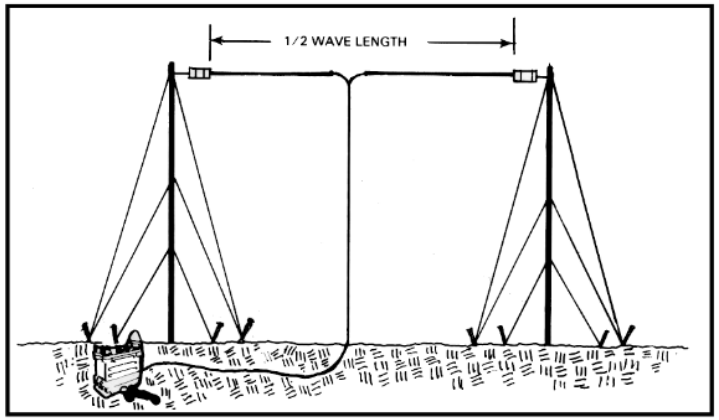
Cushcraft R-8 ($589.95)

Typical elevation radiation pattern



Specifications:	Part Number R8
Frequency meters	6, 10, 12, 15, 17, 20, 30, 40
Gain (dBi)	3
VSWR at resonance	1.3:1 typical
VSWR 2:1 bandwidth, KHz	40m (150) 30m (>50) 20m (>350) 17m (>100) 15m (>450) 12m (>100) 10m (>1500 6m (>1500)
Power Watts PEP (FM)	1500 (500)
Radiation angle, deg.	16
Horizontal rad, deg.	360
Height, ft (m)	28.5 (8.7)
Mast size range, in (cm)	1.25-2" (3.18-5.1)
Wind load, ft2 (m2)	1.5 (.14)
Wind surface area)	2.5 sq ft (0.23 sq m)
Weight, lb (kg)	23 (10.5)
Shipping Dimensions	3-3/4" x 5-1/4" x 84-1/2"

Long-Range Horizontal Antennas



Dipoles

Dipole Antenna Height

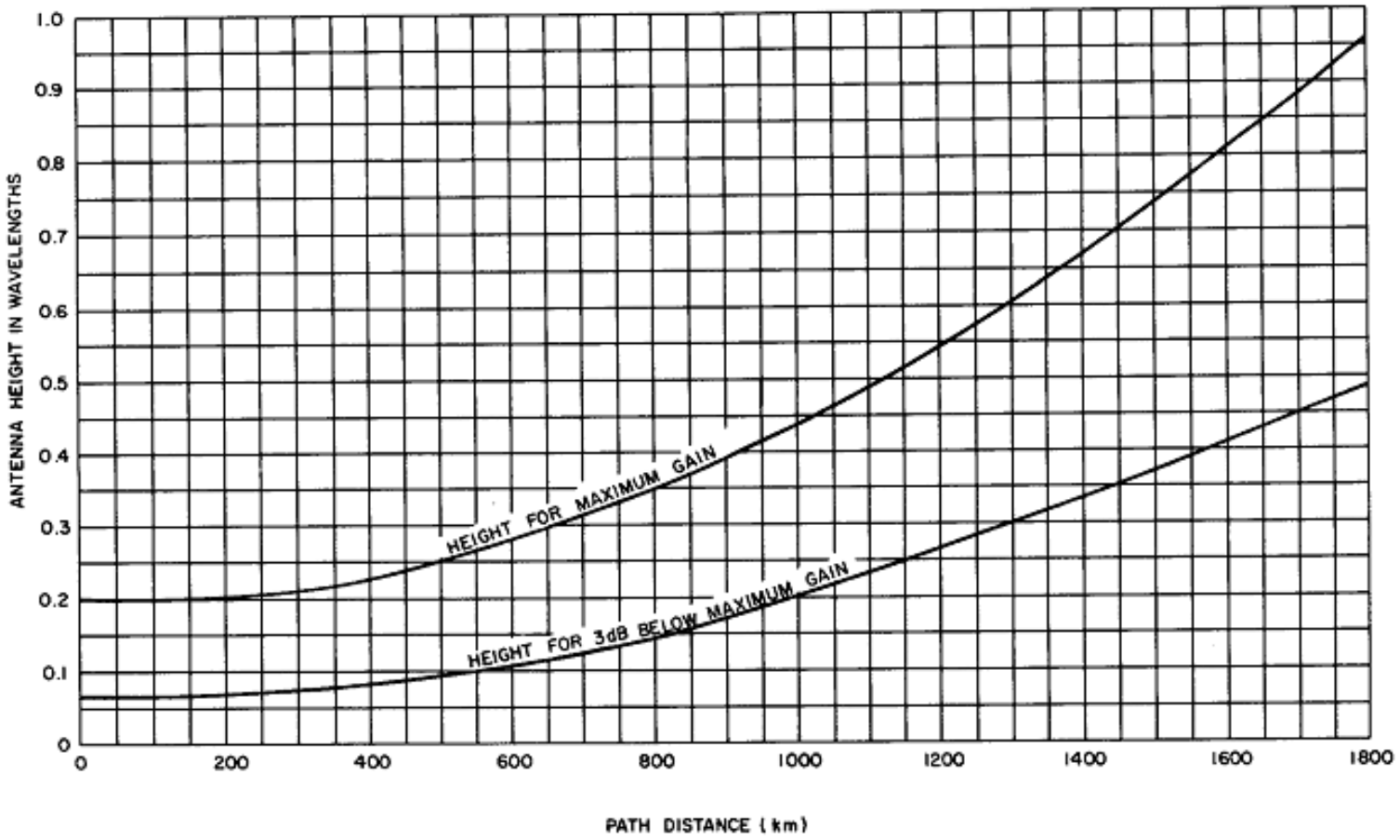


Figure 5–3. Approximate height of half-wave dipole for best F2 layer propagation.

Types of Masts

- Poles – suitable for dipoles and Inverted-V antennas.
  - Fixed sections
  - Telescoping
  - Guyed and self-supporting
- Towers
  - Guyed
  - Self-supporting

Antenna Poles

- Source: http://tmastco.com/main/page_products_mast_sections.html
- Description:
- Military surplus aluminum masting tubes. Each tube is 48 inches long by 1.785 inch outside diameter (inside diameter 1.57 inch), wall - 0.11 inch, and weigh 2.7 lbs each. The last 3.25 inches is a smaller diameter (1.55 inch OD, 1.33 inch ID) that then fits into the next mast section. This 1.55 inch diameter piece is 6 inches long and is used as an inner sleeve that forms a strong joint.
- Prices vary (from $9.50 to $12.00 each) due to the condition of the tube sections and the erratic availability of these through surplus outlets.
- Note that these poles have no external protruding joints, so a PVC pipe “car” can be hoisted up and down the complete mast if only top guying is used.

Pivoting Base Assembly

- Insulated Pivoting Base Assembly (IPBA1)
- This heavy-duty base assembly (used in our Vertical Antenna Kit) is made from two pieces of composite material (high density polyethylene and wood flour) fastened with long lasting stainless steel hardware and includes a heavy duty zinc-plated steel U-shaped pivot piece. Overall length is 11 inches and width is 5.5 inches. A short length (7-inches) of aluminum mast section is included for easy connection to your mast sections. A 3/8-inch diameter zinc-plated steel hinge pin is included to fit the pivot piece. In addition, 4 galvanized 12-inch long ground stakes are included for use when setting the base assembly directly on the ground. The larger section of composite material has 6 drilled holes that will accept the ground stakes, or you can use 3/8 inch bolts (not included) to attach to other surfaces (fence posts, tree trunks, concrete pads, deck floors, etc.). Depending on your total height and top load (antenna, mount, pulley, etc.), you can then easily walk up the mast. The Base Assemby will work with either the standard or ribbed-sided aluminum sections. The pivot piece does not lock into a vertical position; therefore, guying is required to maintain the mast in a vertical position.
- Price is $45.00 each, plus packaging & shipping

Vertical Mast Kit

- Pricing & Ordering of Basic Kit:

VAK1 is $165.00 (plus packaging/shipping to your address).

- Note external coupling joints do not permit sliding “car”

Vertical Kit Mast Assembly

Antenna Assembly 2

- “Car” with SG-230 Auto-tuner and VHF antenna hoisted to top of mast using an internal halyard.
- Must use smooth outside mast sections.
- Only guying required is at top above “car”.

Telescoping Masts

- Must be guyed
- Place pulley at top to raise dipole after mast is securely guyed.
- Both metal and fiberglass are available.
- Fiberglass is better since it does not interact with antenna and does not pose a electrocution risk around power lines.

Fiberglass Telescoping Mast

Site: https://mgs4u.com/fiberglass-push-up-masts/?v=7516fd43adaa#masts

25 feet Heavy Duty Fiberglass Push-Up Mast
MK-4-HD
$159.95

Maximum Usable Length (Height): 25 feet
Length when sleeved: 5 feet and 6 inches
Minimum overlap of tubes: 4.25 inches
Length of Tubes: 46.5 inches
Outer Diameter of Bottom Section: 2.5 inch
Outer Diameter of Top Section: 1 inch
Total Number of Sections: 7
Weight (when assembled): 12 pounds

Note: I used J-B Weld Epoxy to glue quick clamps onto each section

Self-Supporting Pole Mast

- MARS member has used a 3.5 “ diameter, 40 ft. drill stem pipe to support a large NVIS fan dipole antenna for 20 years. Pipe is set in concrete, depth unknown, but probably >5 ft.
- See for example: https://www.chingosofpipe.com/pipe/
- Place high-quality pulley at top since you will not have access once pole is set.

Triangular Towers
(Personal Experience Only)

- Guyed
  - Hazer
- Tapered self-supporting
  - Fixed height
  - Crank Up

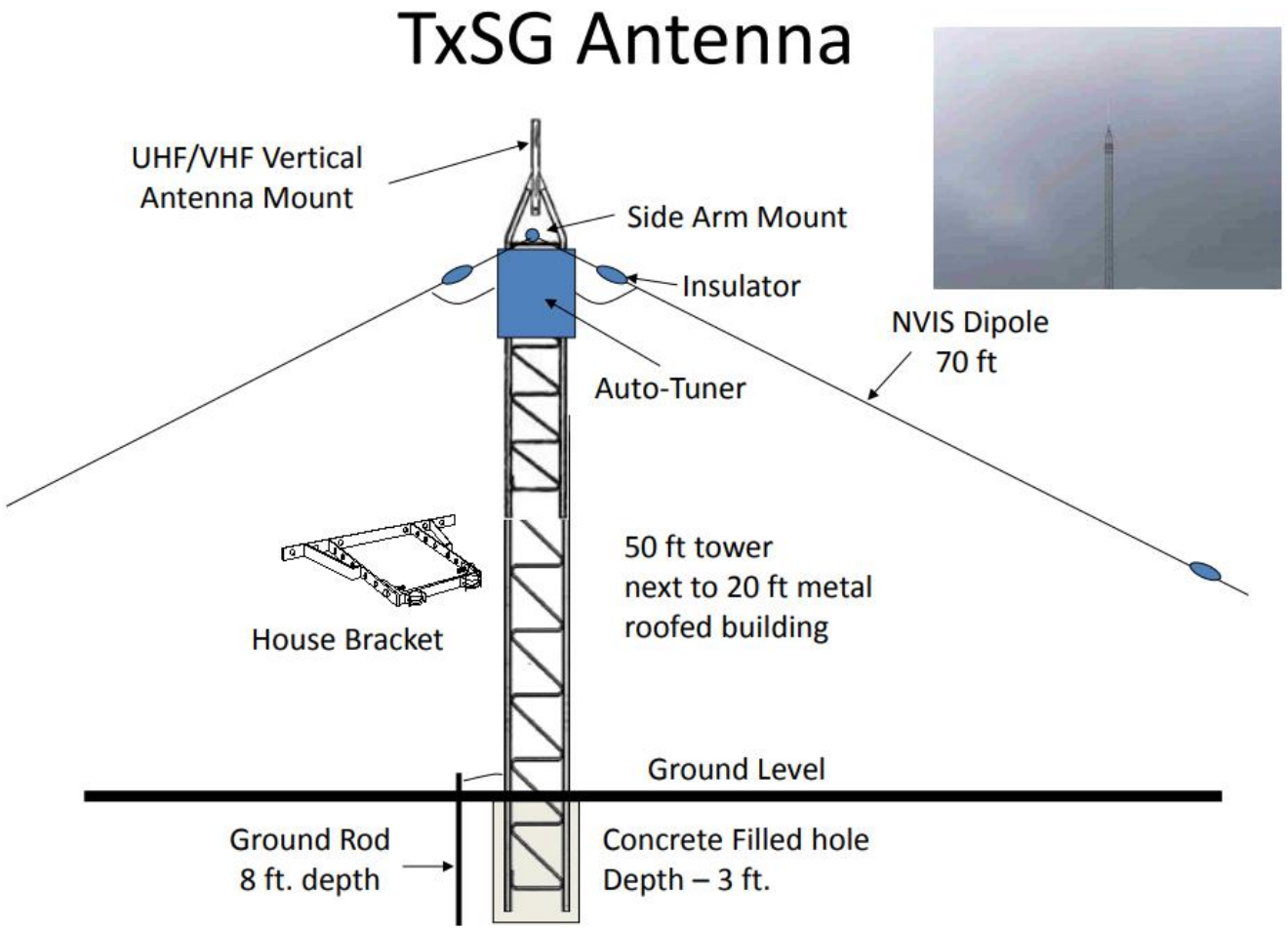
Tower Wind Loading

- Towers designed for mounting horizontal antennas will have a maximum stated wind load given in Sq. Ft. of largest recommended antenna at a given wind speed.
- Each Yagi antenna will list its Sq. Ft. area.
- The tower and antenna selections are matched so that the antenna tower is not overloaded by too large an antenna. Note that the height of the antenna above the top of the tower must be taken into consideration since this additional height increases the rotational moment loading.

Rohn 25G – 80 ft.

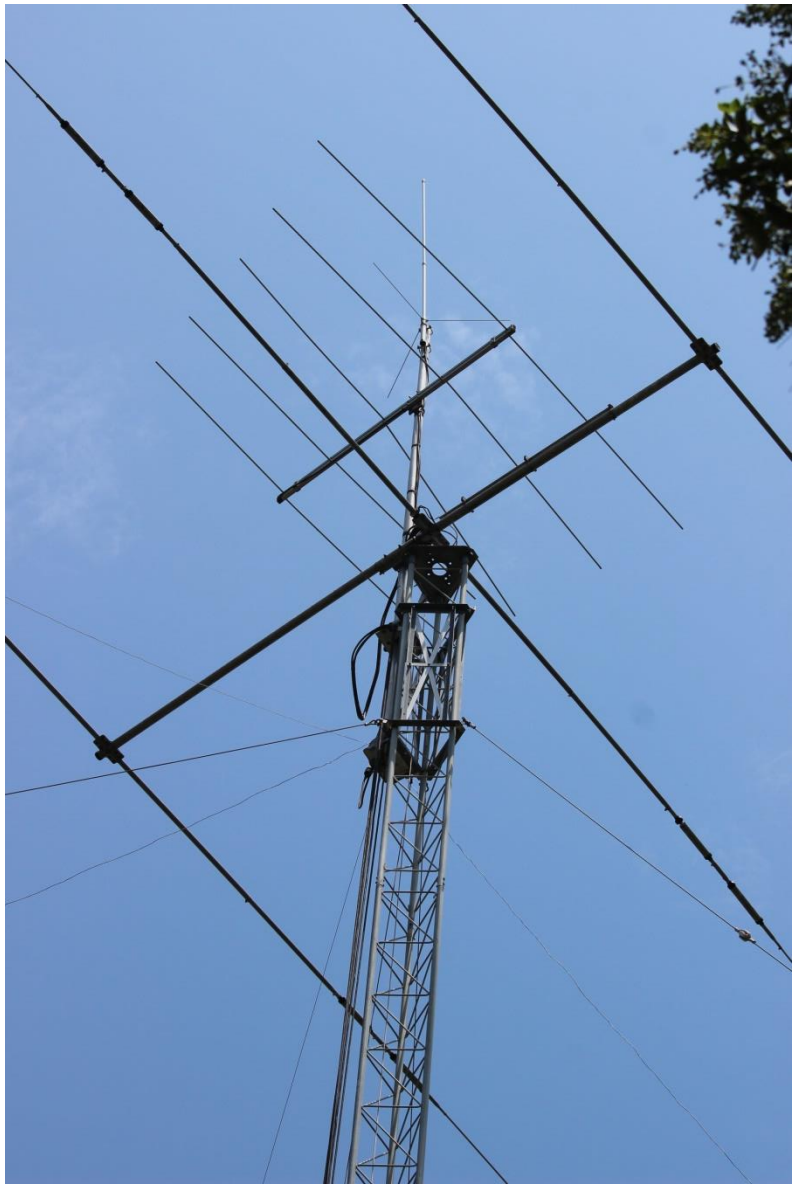
Two Point Anchor of Rohn 25G

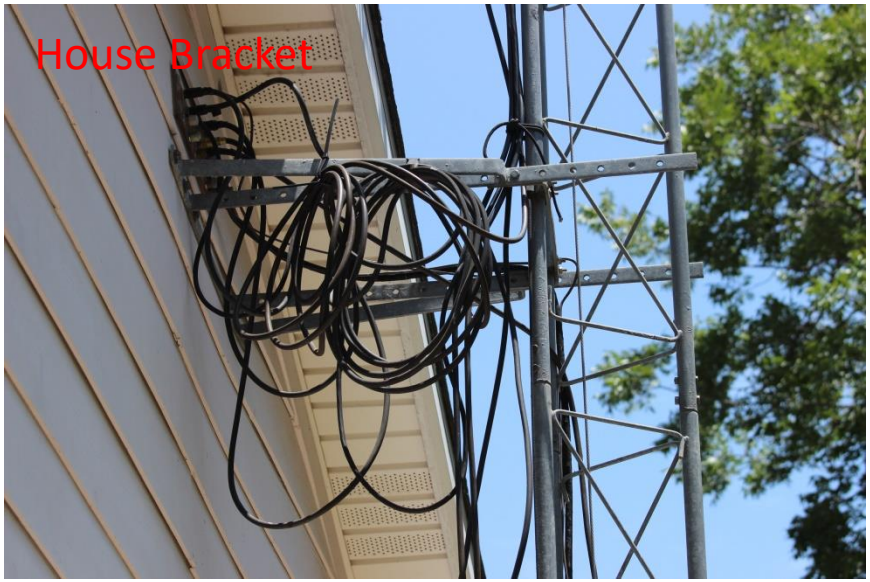
- Rohn 25G is man-climbable to 50 ft. when base is set in concrete and a strong house bracket is used at a height of 15-20 ft.

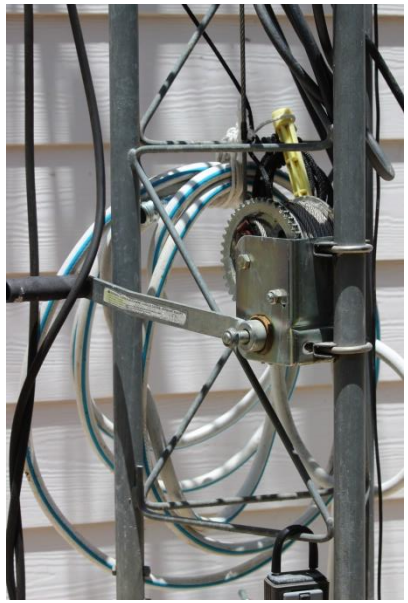


Two Point Anchor with Glen Martin Hazer

K5GM 60 ft. Hazer Antenna System







Hazer Winch

K5GM Hazer System

Advantages:

- Can lower Antenna system to roof top for maintenance.
- Only have to climb tower to top once to install pulley.
- Does include fail-safe lock

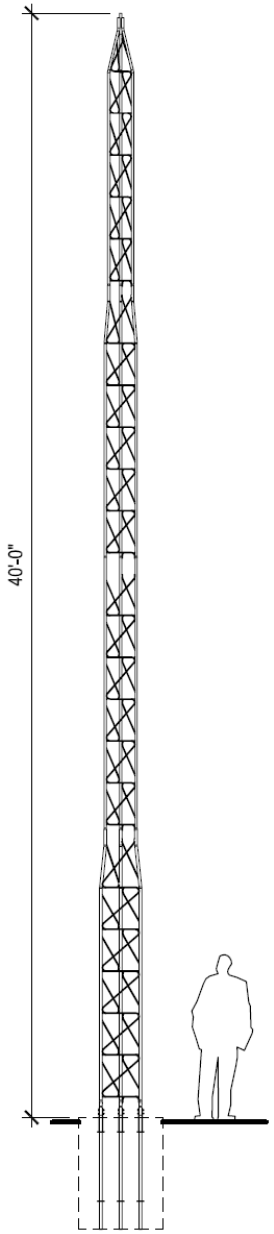
Free-Standing Tower

Type: Freestanding Aluminum
Universal Towers Model #4-40

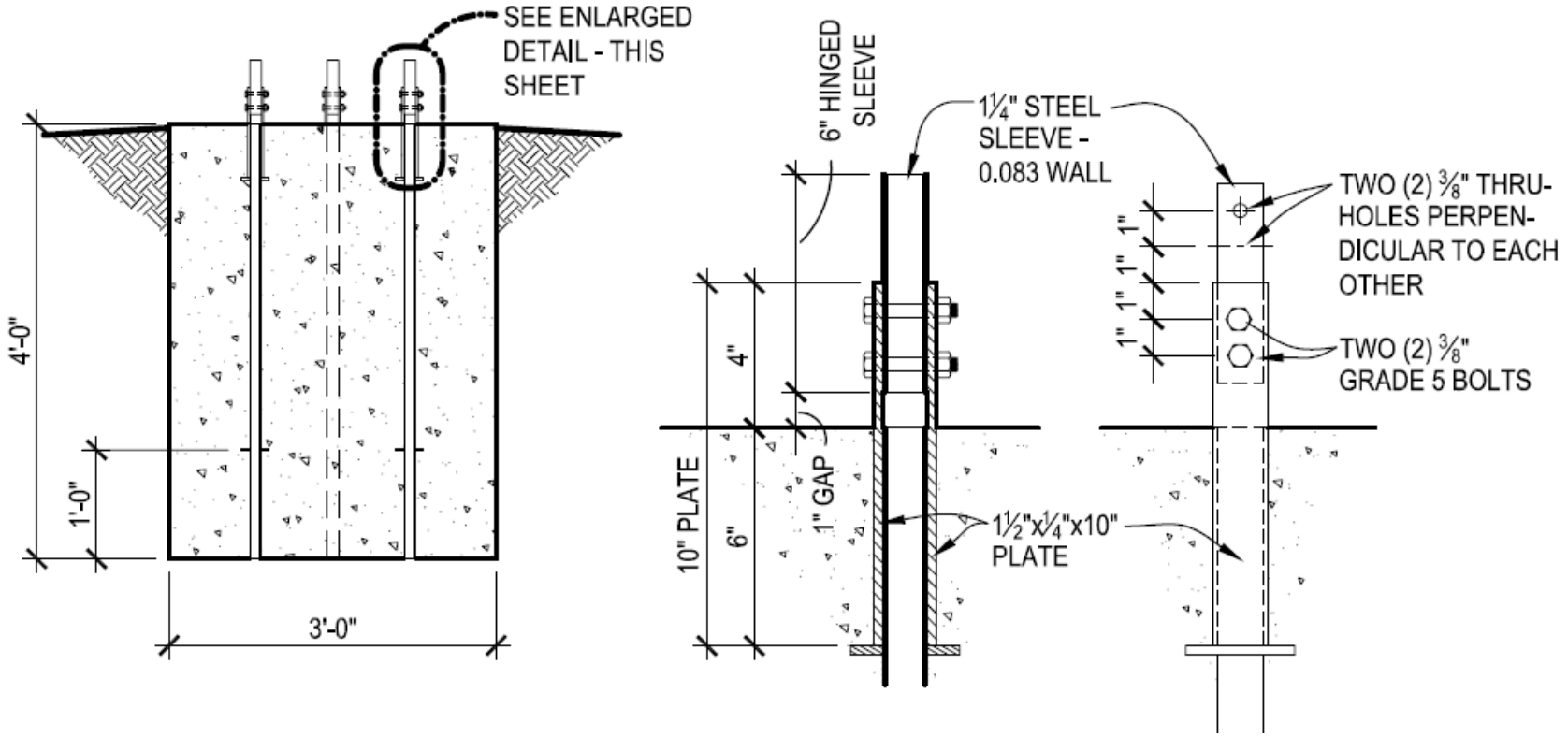
TOTAL WEIGHT: 68 LBS.

WIND LOADING:

80 mph	4.5 Sq. Ft.
100 mph	2.5 Sq. Ft.
110 mph	1.5 Sq. Ft.

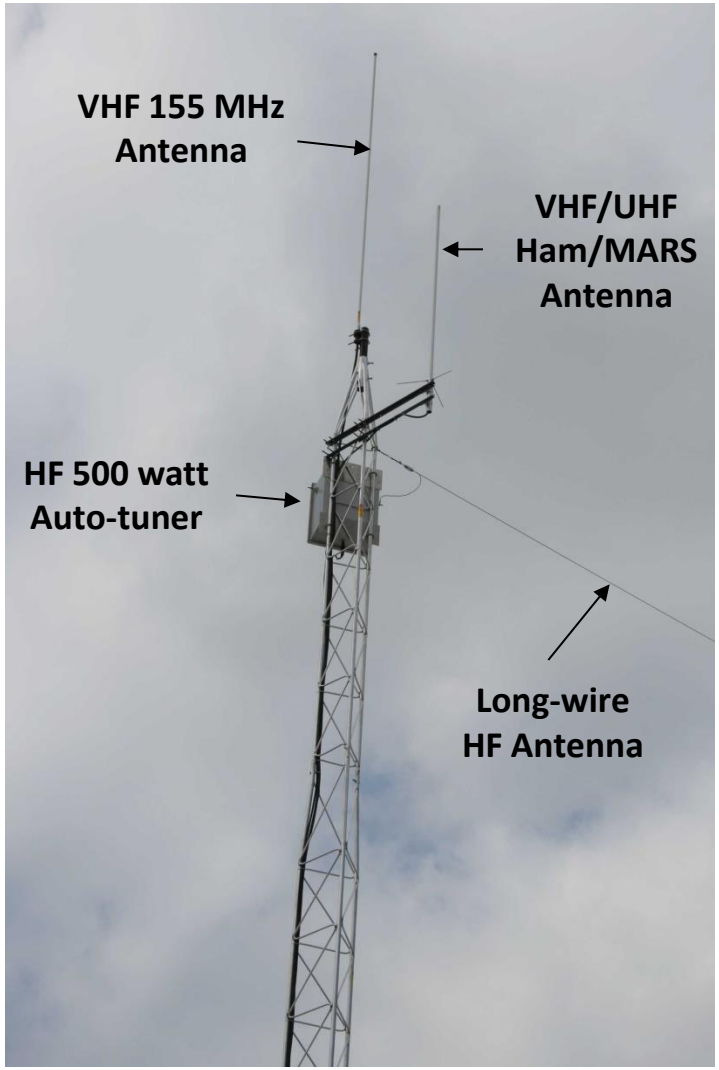


TOWER BASE DETAILS



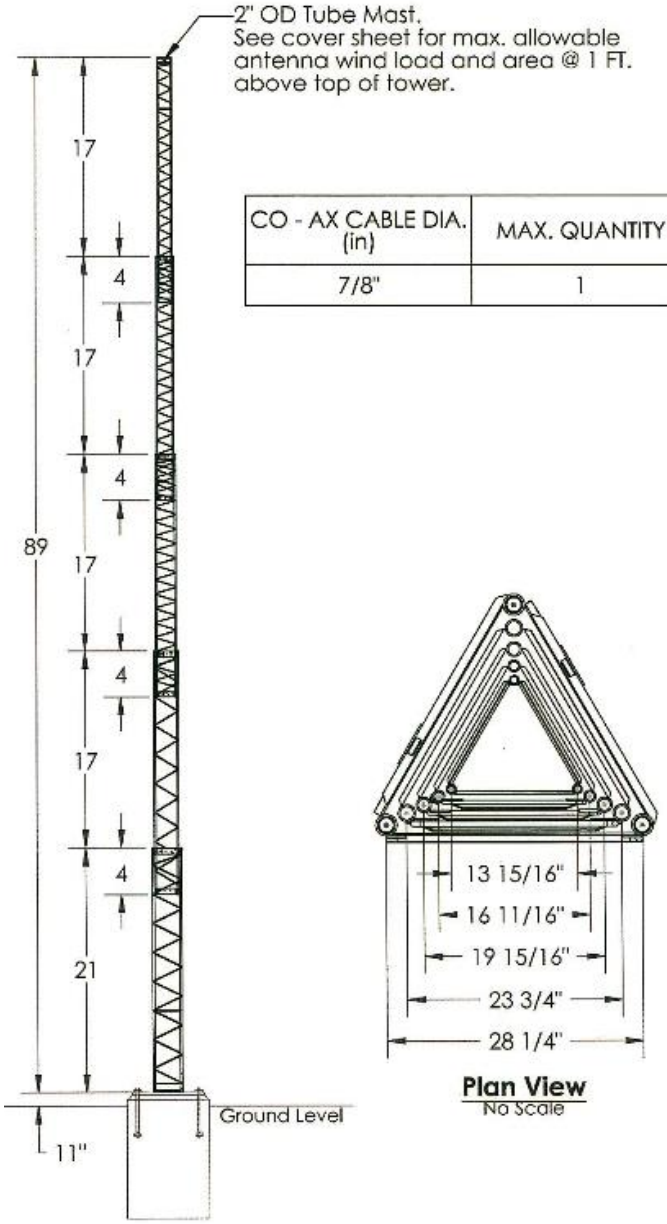
BASE CONSTRUCTION

Free-Standing Tower at Camp Mabry



Free-Standing Crank-Up Tower

- Model – US Towers HDX-589MDPL
- Maximum Height – 89 ft.
- Nested Height – 24 ft.
- Weight – 2665 lbs. with motor drive
- Bottom Section – 30 5/8 inches
- Foundation – 5 ft. X 5 ft. X 8 ft.
- Motor Drive – 120 VAC positive pull-up and pull down.
- Wind Load – 9.2 sq. ft. at 90 mph 3 sec. gust
- Safe Height for DB-36 at stated wind load – 73 ft.
- Cost of Tower – $17,772
- Cost of Foundation and installation – $53K



J6 HF Antenna Tower

Near Bldg 18, Camp Mabry
28 Jan 2014

SteppIR DB36 Antenna
w/80m kit
& truss kit(s)

US Tower
HDX-589MDPL
89' Telescopic Tower

Mast

Rotator

70' wire

70' wire

89'

rope

rope

Cables on Tower (5 standoff arms)
1 x LMR400UF coax cable
1 x 8 cond rotator cable
1 x 24 cond antenna control cable
1 x 450 ohm ladder line

Custom Remote Antenna Tuner &
NVIS Antenna (provided by TXNG)

HF Station 2nd Floor
West end of Bldg 10

Bldg 18

Power
120V 20A

Motor Drive

Lightning Arrestors
SteppIR Remote Driver Board (Ant Control Cable to Cat 5)
Green Heron Wireless Remote Board (Rotator Control)

Power

New Conduit to be installed

Base footing
5' x 5' x 8' concrete
with rebar cage
(7.5 yards concrete)

2 x LMR600 coax cable (up to ~700ft)
1 x Cat 5 antenna control cable (up to ~700ft)
In existing underground conduit

POC:
Brian Attaway
Director, J6
512-782-6946
brian.attaway@us.army.mil

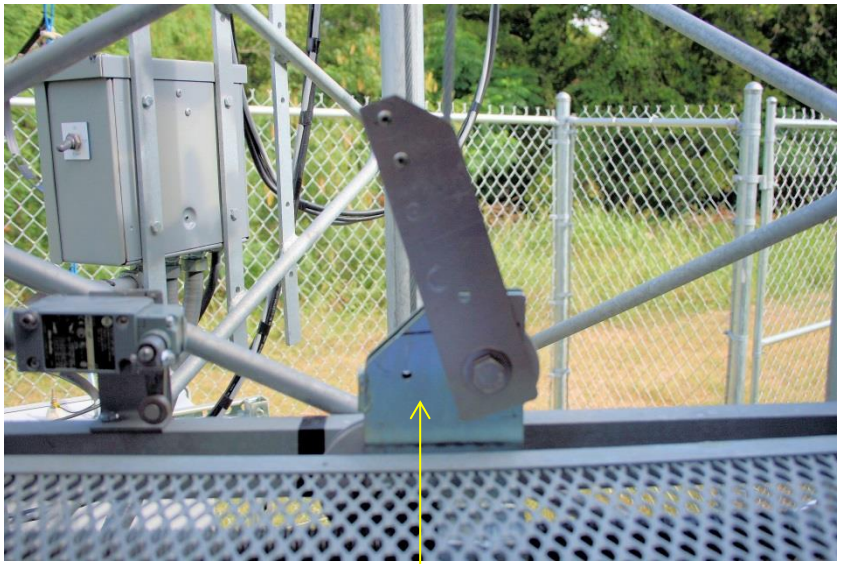
US Towers Recommendations

Hi Mr. Thompson,

The load characteristics for the tower with the antenna indicated (StepIR DB36, with sail area of 17.5 sq.ft.) come out as follows:
96 mph for a maximum elevation of 73’
78 mph for 89’
I will recommend to follow the standard operation procedure and lower the tower if winds over 50 mph are expected.

Regards,
Remigio Fernandez-Garcia
Civil Engineer
US Tower Corp.
1099 West Ropes Ave.
Woodlake, CA 93286
559-564-6000 ext. 130 | Fax: (559) 702-2560
rfernandez@ustower.com | www.ustower.com

70 ft. Limit Switch



70 ft. Limit Switch Deactivated. Tower Limit is now 89 ft. The dipole Center halyard, wrapped around section 4, must be deployed to prevent damage to dipole. Note also that there is a potential for tower failure during high wind events.

QUESTIONS?

Lewis Thompson
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