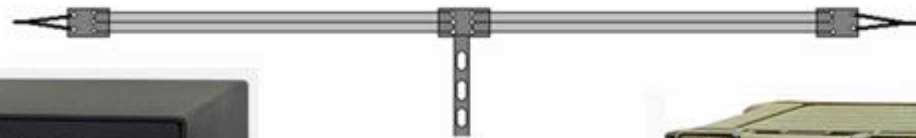


Wide-Band HF Antennas

Lew Thompson

W5IFQ

3 FEB 2026

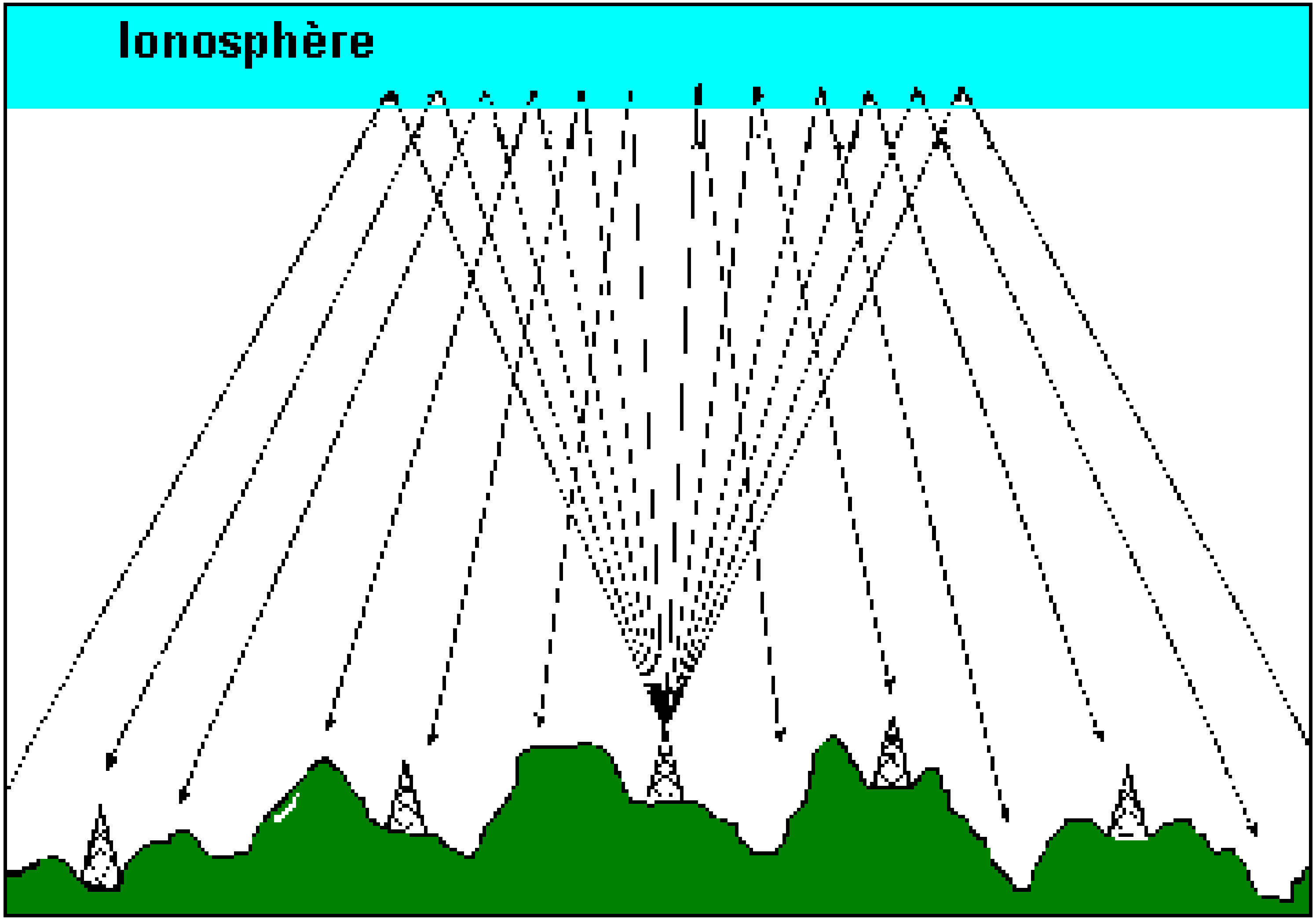
Objectives

- Introduce Wide-Band HF Antenna Theory and Practice
- Demonstrate that a single, horizontal wire antenna can provide both NVIS (Near Vertical Incident Sky-wave) and Long-Range propagation.

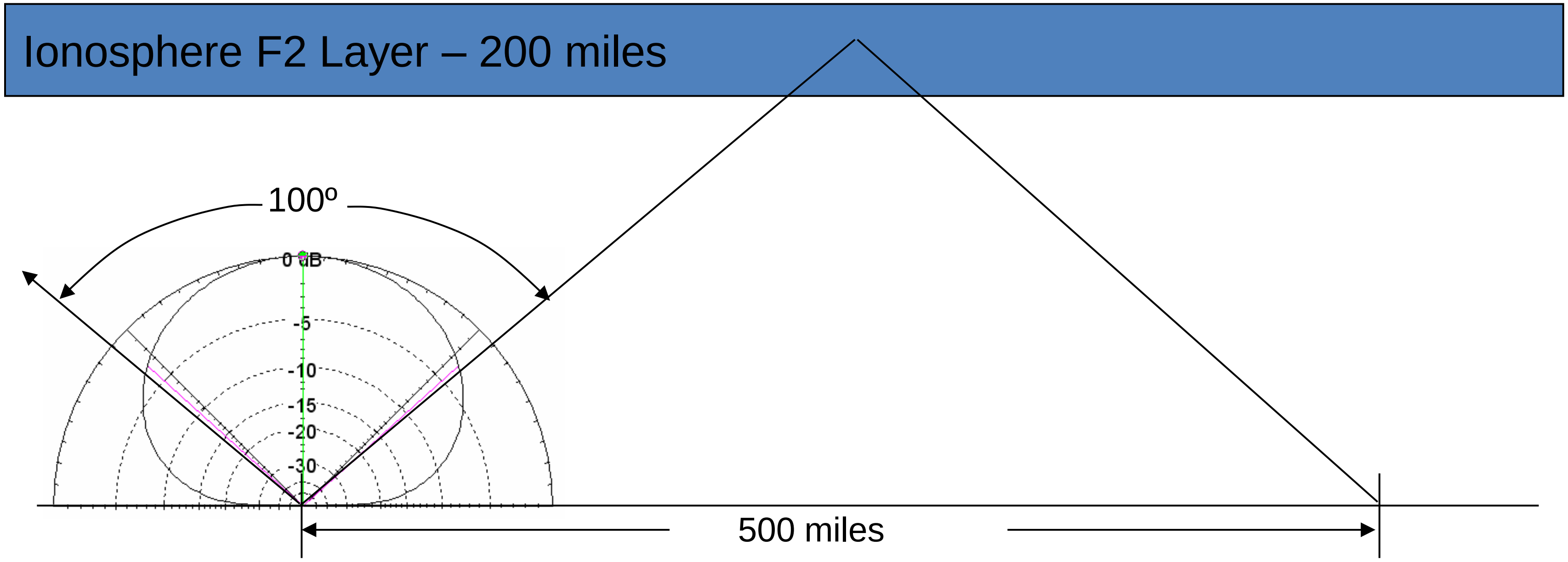
Antenna Propagation Theory Outline

- NVIS Propagation (0 – 500 miles)
- Long-Range Propagation (>1000 miles)
- Operating Frequency Selection

NVIS Propagation



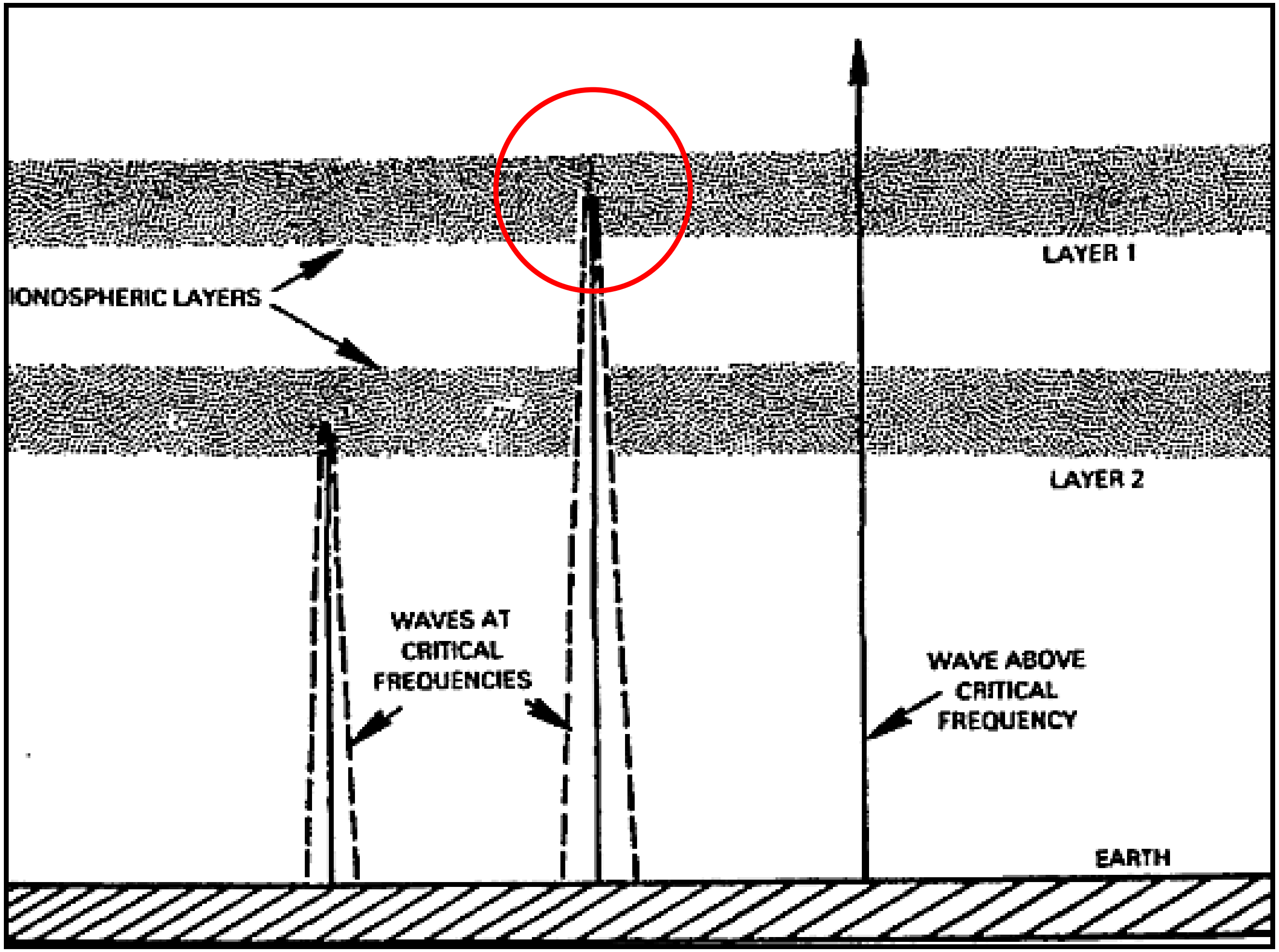
Required NVIS Antenna Pattern



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

Critical Frequency Definition

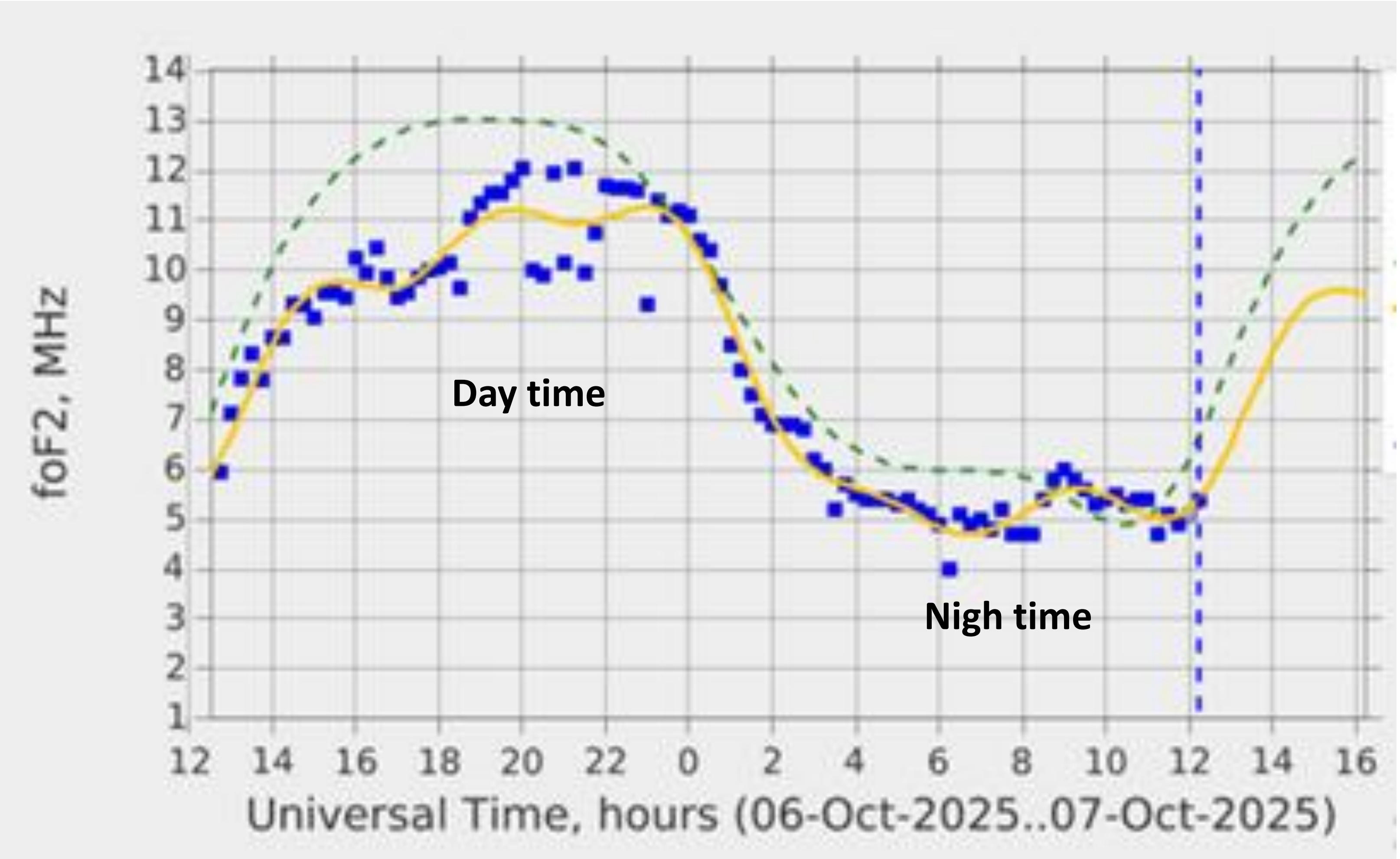
- Must operate at or below the local Critical Frequency (CF) in the F2 layer to achieve NVIS Propagation.



Factors Affecting Critical Frequency

- Critical Frequency increases with increased ionization of F-layers
  - Time of day
  - Time of year (Summer Anomaly)
  - Time of the 11-year sun spot cycle
- Other factors
  - Geomagnetic storms (CME and Coronal Holes)
  - Terrestrial heating (summer anomaly)
- NVIS propagation is very sensitive to the correct selection of the Critical Frequency.

Critical Frequency (foF2) vs Time Austin Ionosonde



Monthly Solar Weather
Presentation to AARC

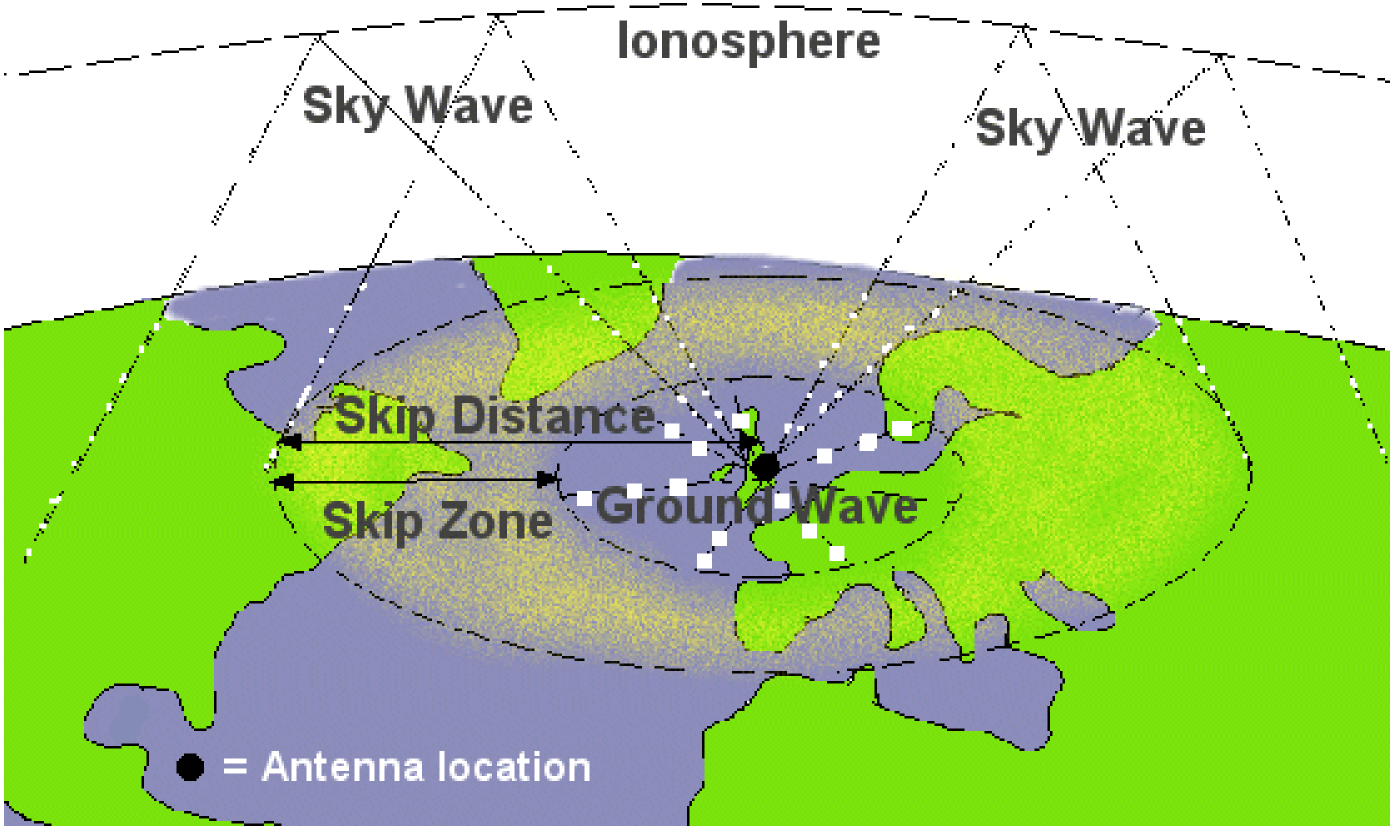
SOLAR WEATHER
4 NOV 2025

Lewis Thompson
W5IFQ

Taken by PAUL D. MALEY on October 29, 2025 @ Egilsstadir, Iceland

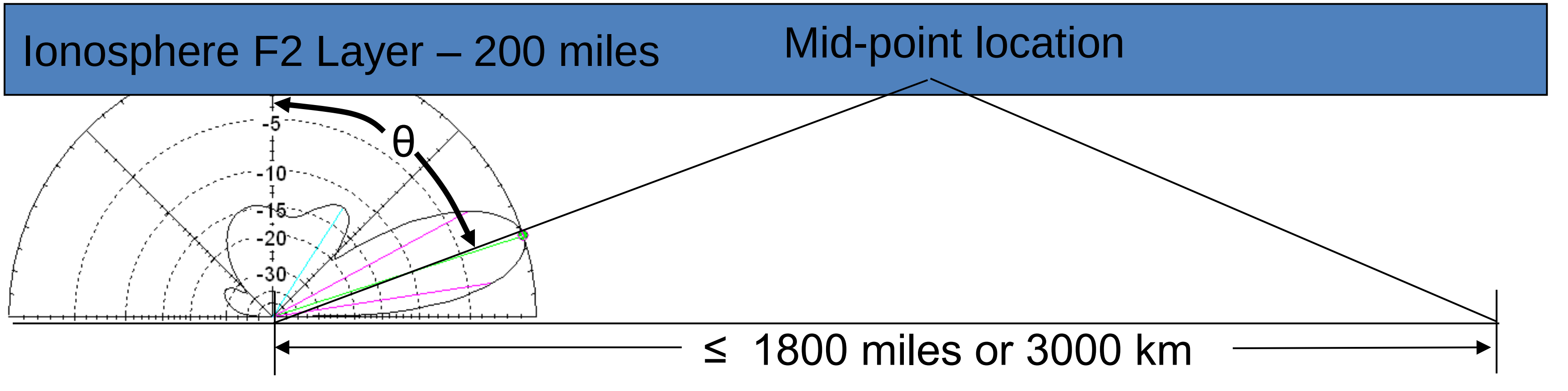
Taken by Thomas McCarty on October 30, 2022 @ Fairbanks Alaska

Long Distance Sky Wave



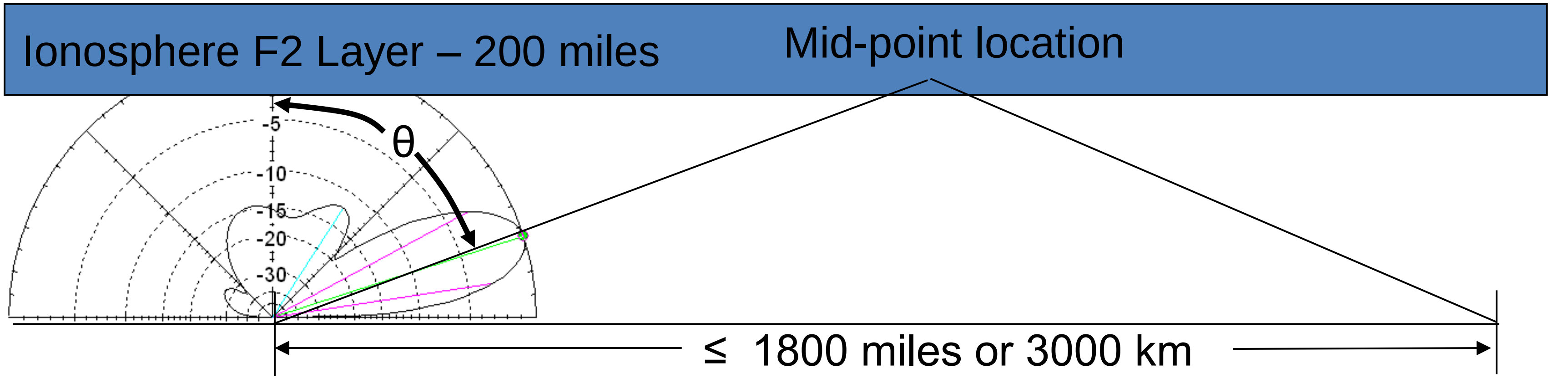
Simplified HF Sky Wave Propagation

- A successful Sky-wave propagation path requires that the Maximum Useable Frequency (MUF) at the **reflection** location be equal to or exceed the operating frequency.
- The required MUF is dependent on Cosine of the TOA.
- For simple F2 layer to earth bounces, this requirement must be met for each succeeding reflection for a multi-hop circuit.

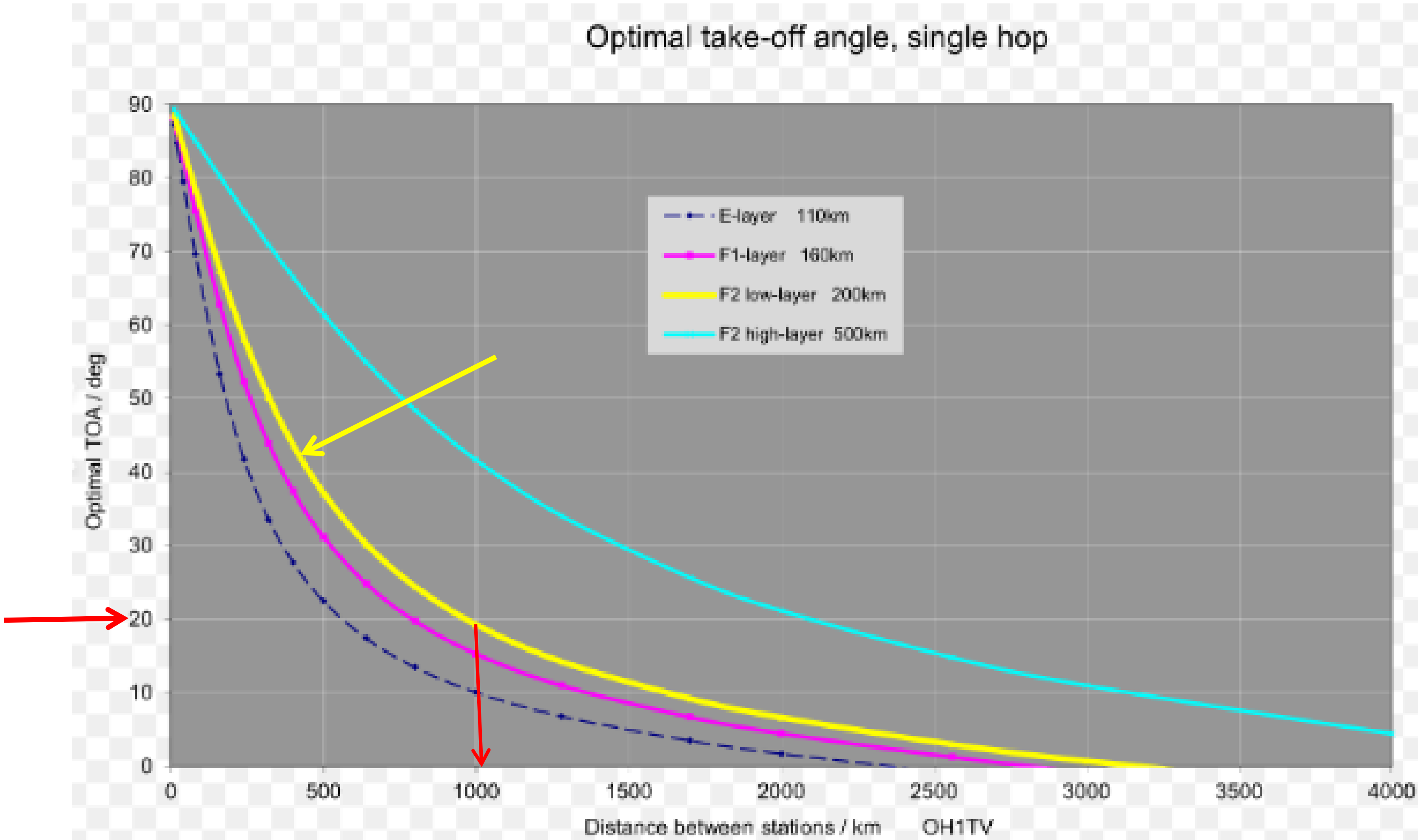


Maximum Useable Frequency (MUF)

- MUF (Maximum Useable Frequency) is Critical-Frequency/cosθ, where θ is the angle from the take-off beam to vertical.



TOA Versus Range



Frequency versus Wavelength

- When designing antennas, the length and height in wavelengths determines the antenna characteristics. It is easier to work in wavelengths and then convert to actual dimensions at the design frequency(s):

  λ (wavelength, ft.) = 983.6/f (frequency, MHz)

- A convenient lookup table follows.

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				

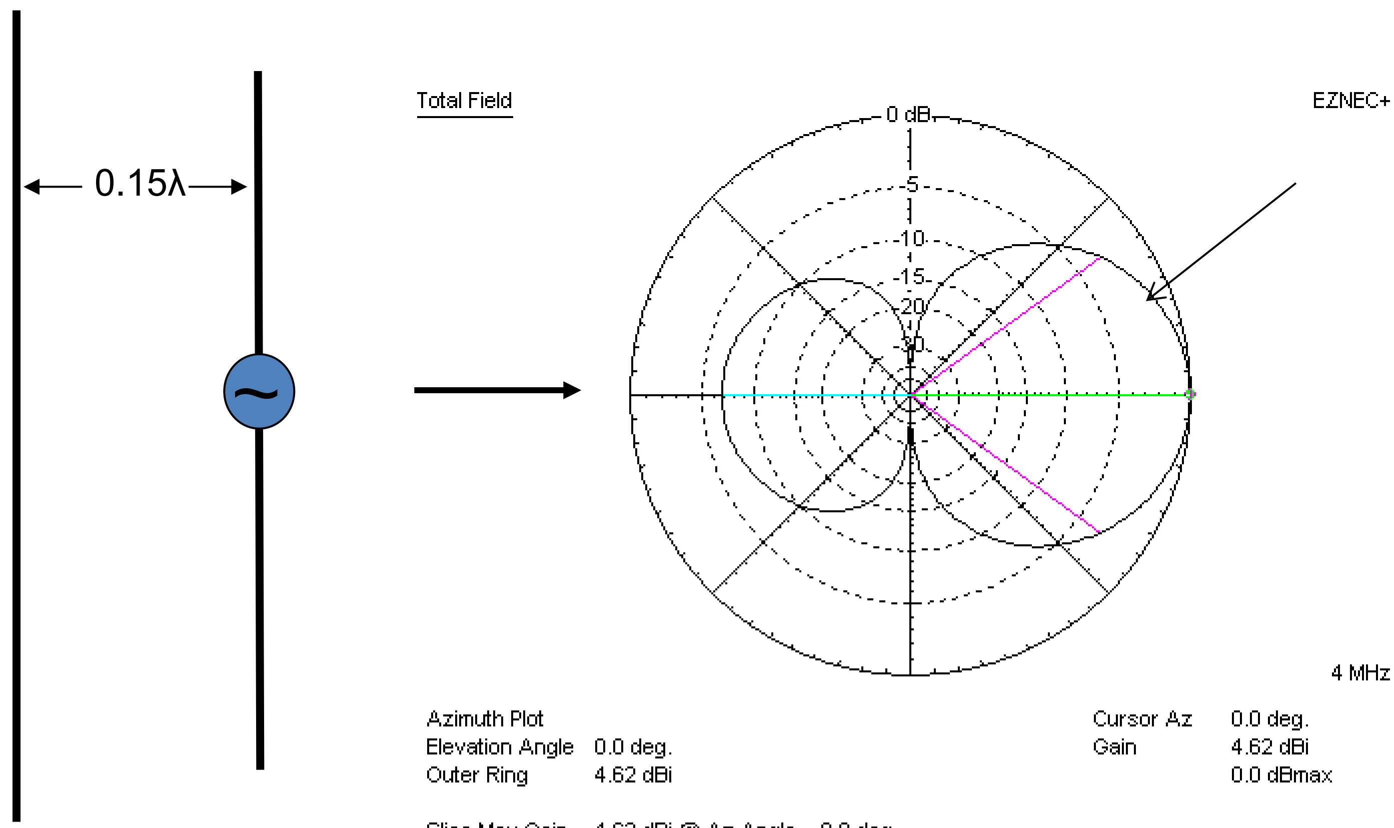
Minimum NVIS Height

Maximum NVIS Height

Long-Range Height

Creating A NVIS Pattern (Theory)

(Free Space)

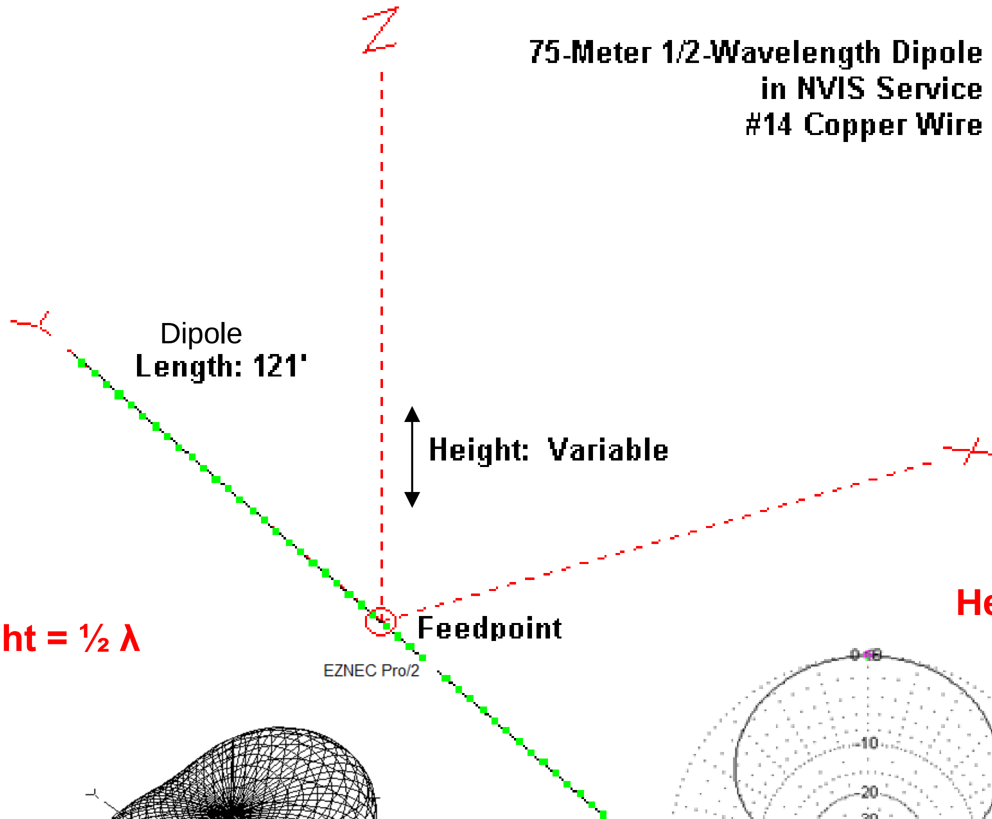


Azimuth Plot		Cursor Az	0.0 deg.
Elevation Angle	0.0 deg.	Gain	4.62 dBi
Outer Ring	4.62 dBi		0.0 dBmax

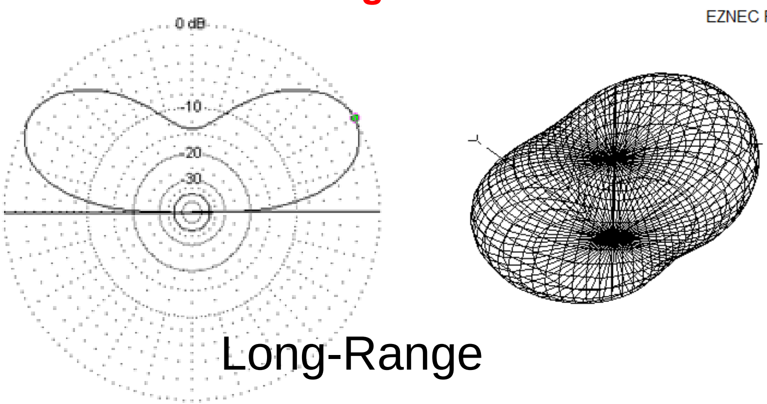
Slice Max Gain	4.62 dBi @ Az Angle = 0.0 deg.
Front/Back	6.77 dB
Beamwidth	72.0 deg.; -3dB @ 324.0, 36.0 deg.
Sidelobe Gain	-2.15 dBi @ Az Angle = 180.0 deg.
Front/Sidelobe	6.77 dB

Dipole Directivity versus Height

(1/2 Wavelength Dipole)

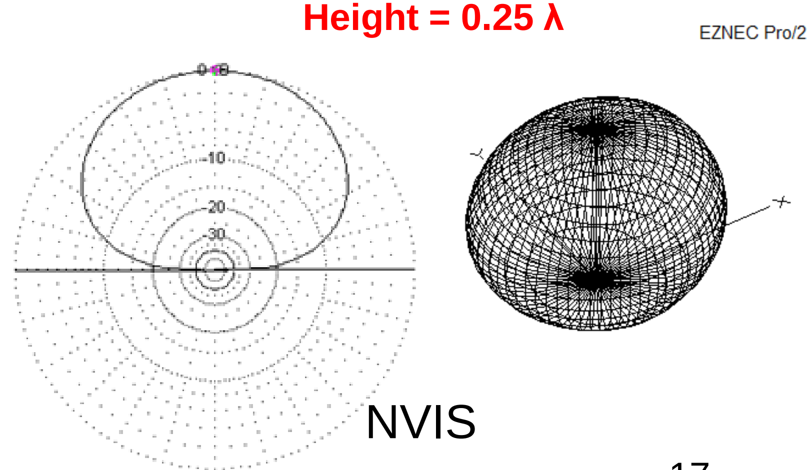


Height = ½ λ



Long-Range

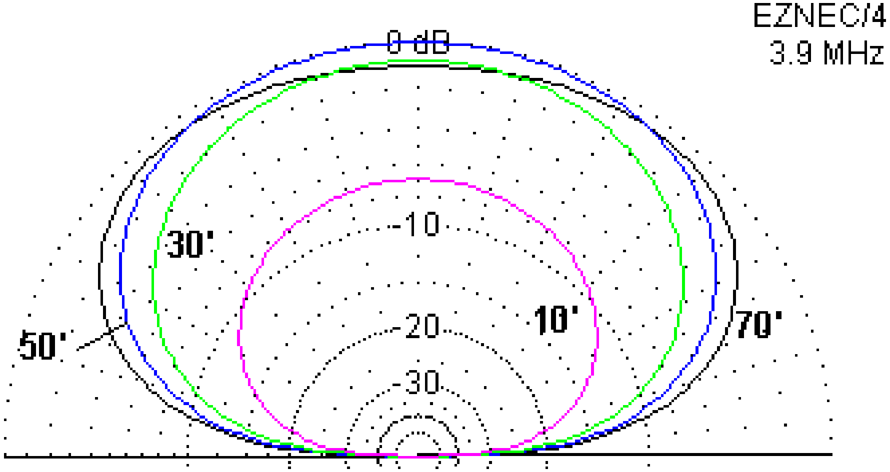
Height = 0.25 λ



NVIS

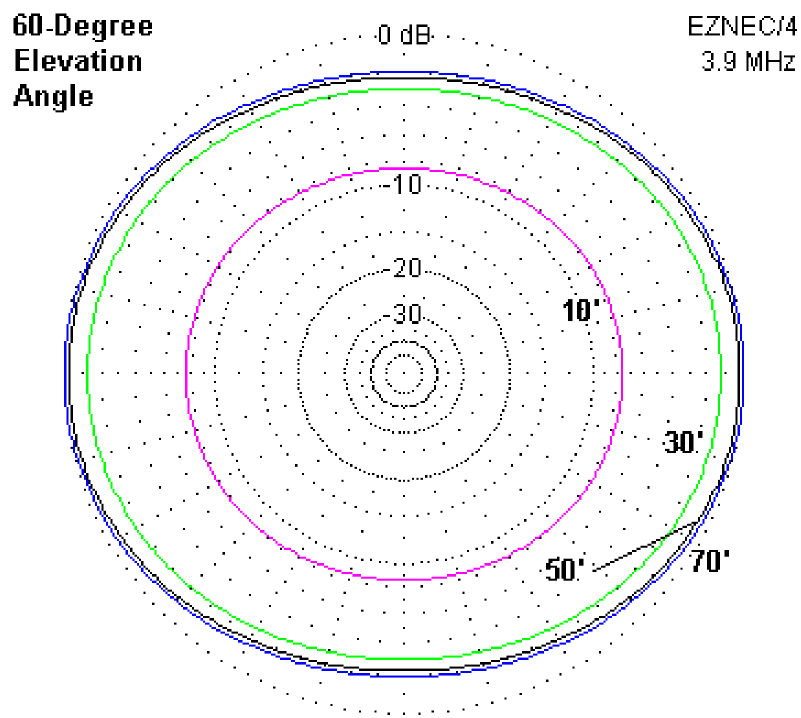
NVIS Dipole Patterns Versus Height – 3.9 MHz

Note: 30-50 ft.
Best practical height



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

50 ft. = 0.2λ
30 ft. = 0.12λ



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

NVIS Antenna Models and the Ground Type
By L.B. Cebik, W4RNL

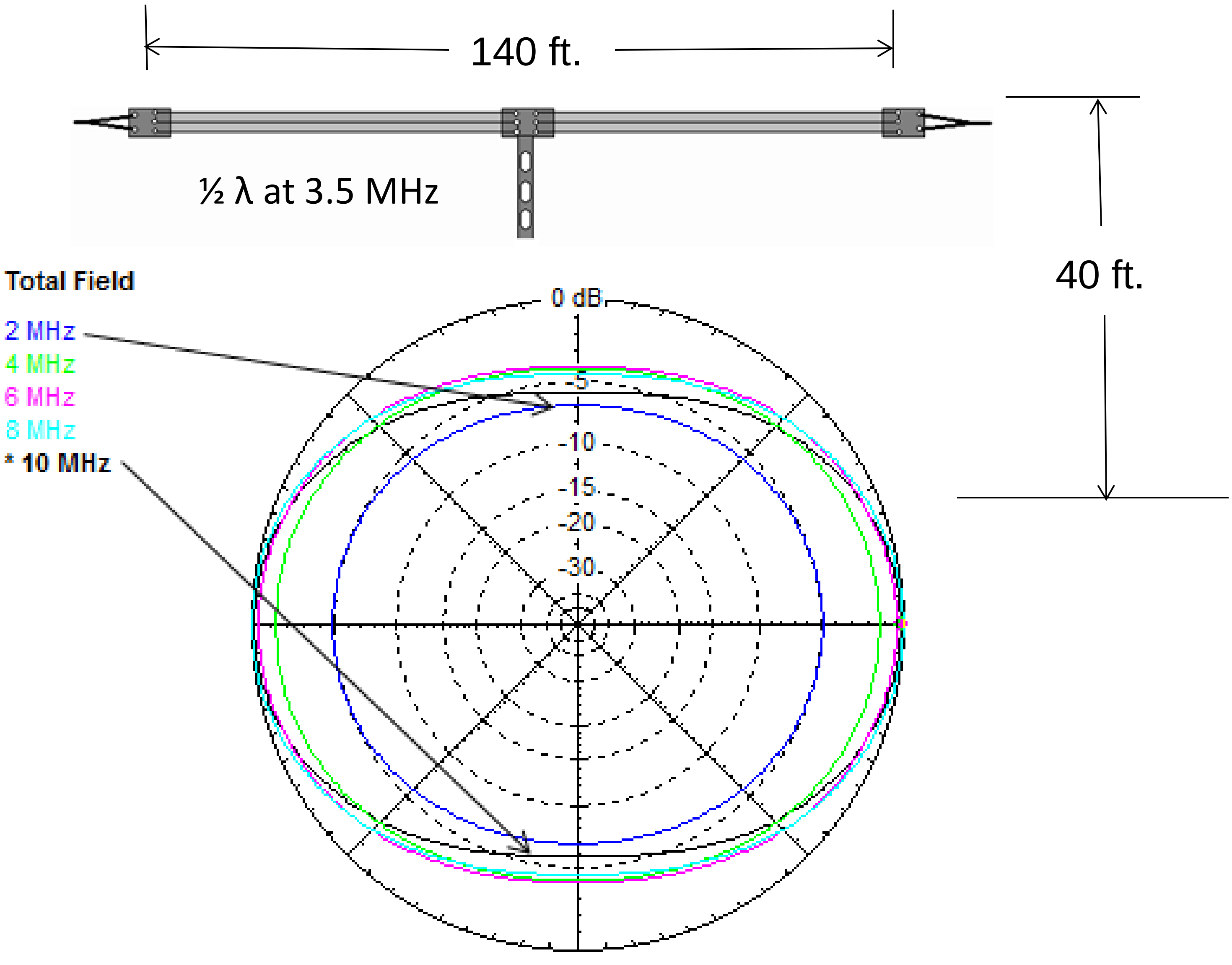
Basic NVIS Antenna Rules

- Excellent antenna is a resonant ½ λ horizontal dipole at 0.15 λ to 0.25 λ height.
- Good performance from 0.1λ to 0.25λ
- Inverted-V is some 2-3 dB worst than dipole, but has more uniform horizontal pattern and is easier to implement!
- Vertical antennas do not generate a NVIS pattern.

Broadband NVIS Antenna Design Length Limitations

- To operate just below Critical Frequency your antenna needs to operate from 3.8 MHz to 10 MHz amateur bands (75m, 60m, 40m, maybe 30m).
- When the antenna **horizontal length** exceeds 1 λ, the horizontal (azimuth) NVIS pattern departs from omni-directional response and becomes increasingly more directional even when the correct antenna height is maintained.
- Careful selection of proper antenna length and height will allow both NVIS and Long-range propagation.

Single Broadband Dipole – Cobra Senior

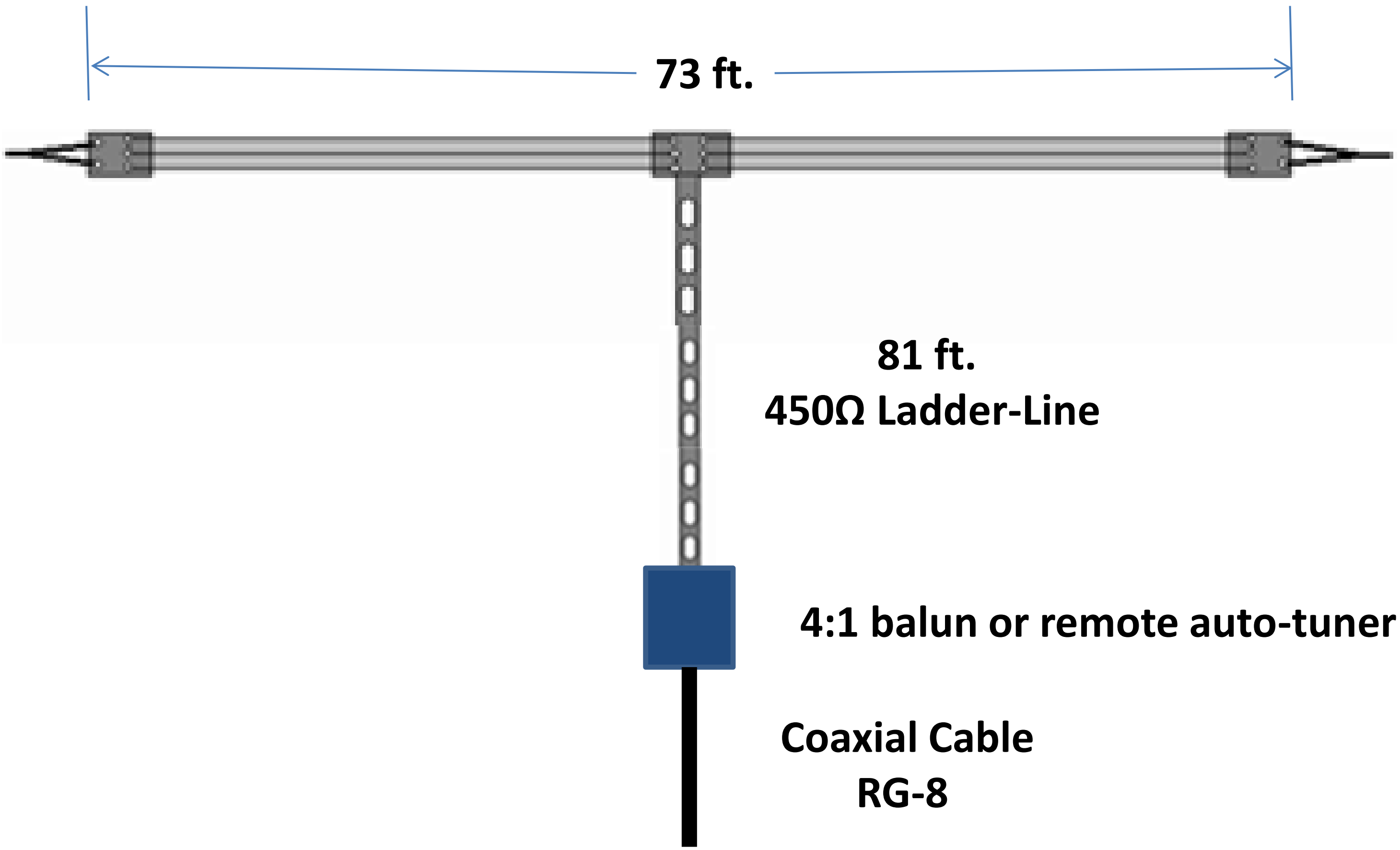


Secret To Good Broadband Antenna performance

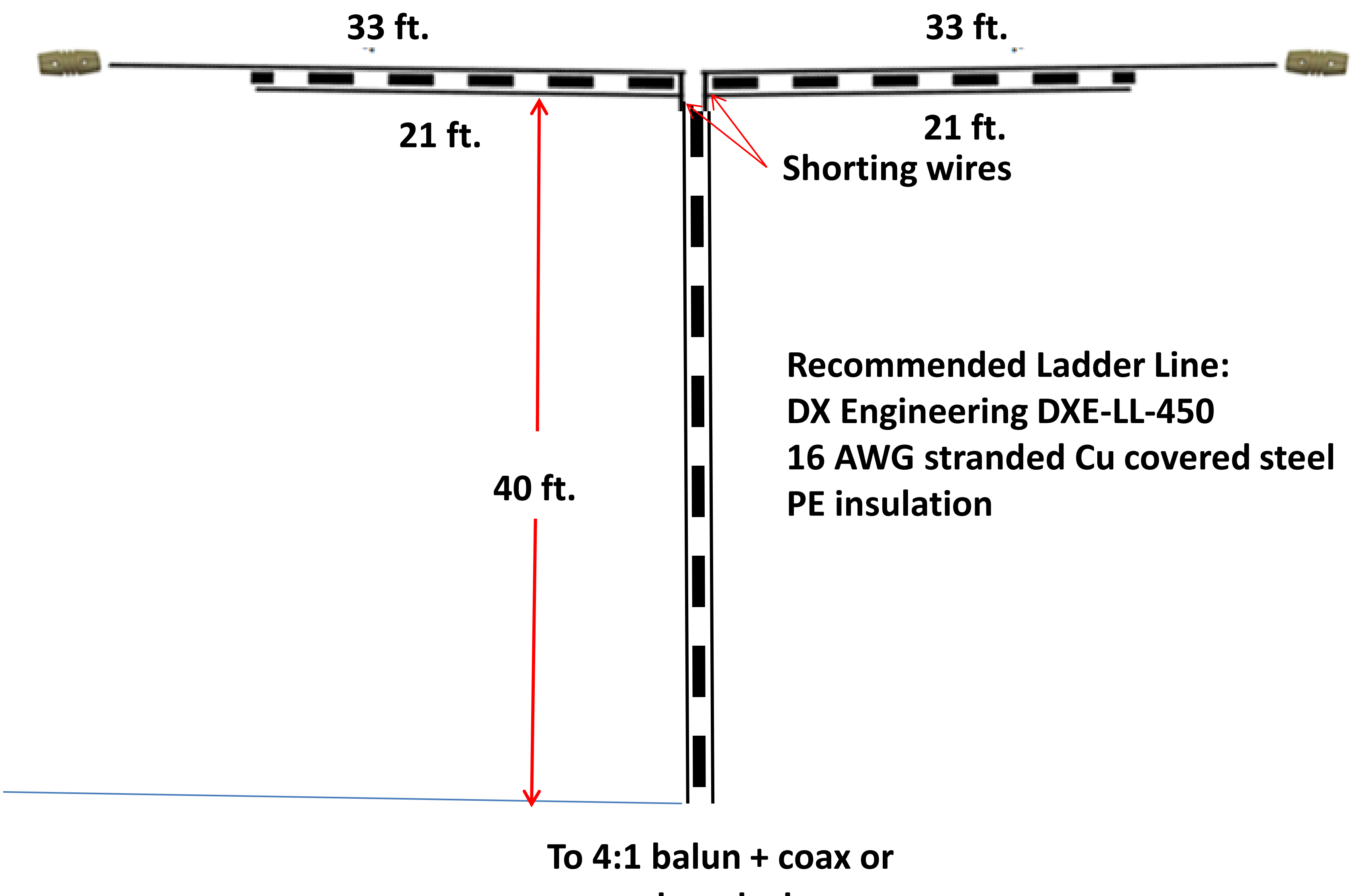
- Use of very low loss transmission Line (450 Ω Ladder Line)
- Selection of proper antenna length (< 1 wavelength) See page 23, 24 and 25.
- Selection of effective height (35 – 40 ft.)
- Operation at proper frequencies for range (NVIS or Long-Range Skip).
- Orientation of antenna for long-range performance (Broad side pointed toward station).
- Use of low loss external antenna tuner and balun

Cobra Ultralite Junior

Cobra Ultralite Junior



Netcom Ladder-Line 66/44



ANTENNA PERFORMANCE

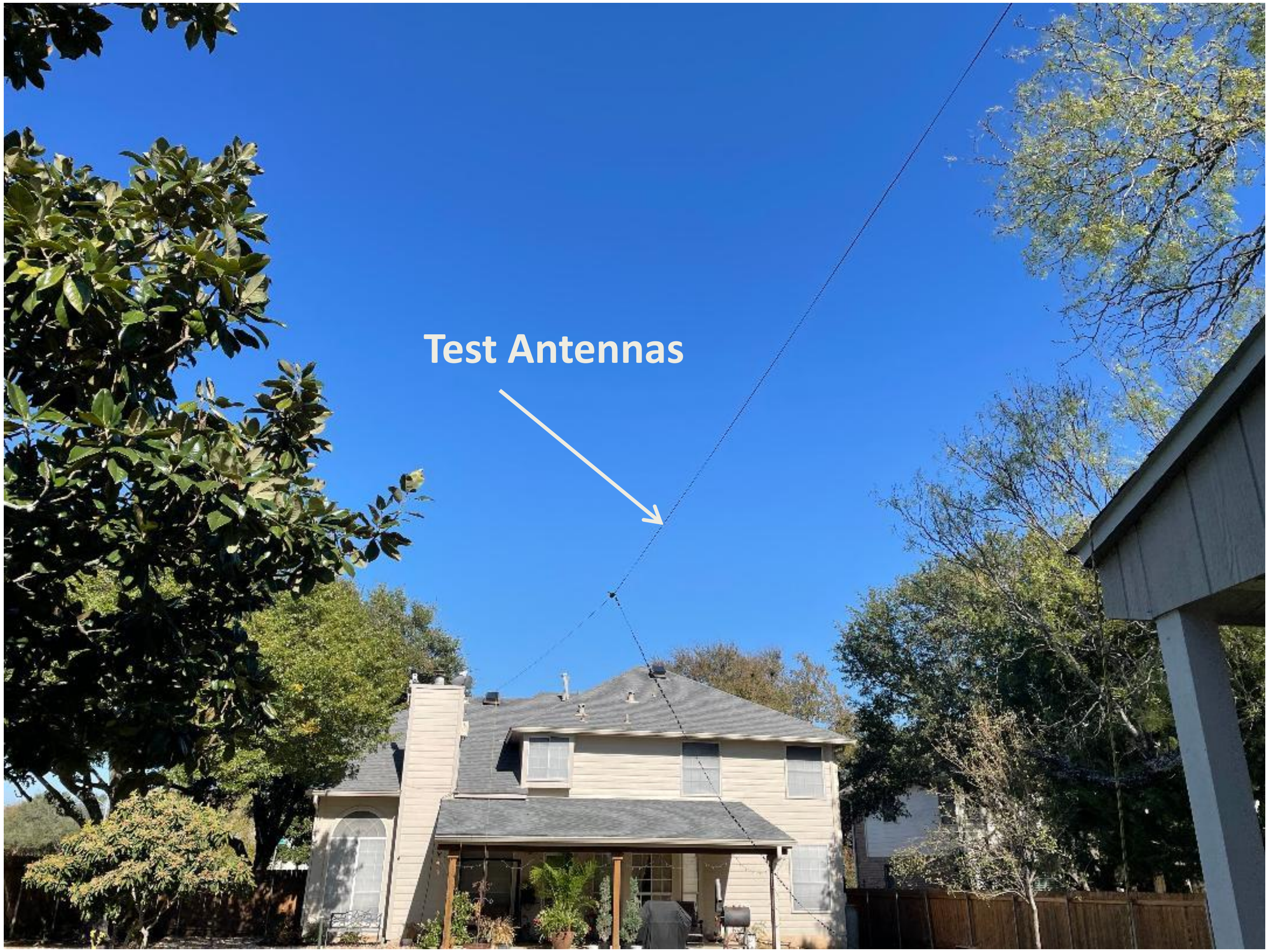
COBRA ULTRALITE JUNIOR ANTENNA

NETCOM 66/44 LADDER LINE ANTENNA

Test Antenna Limitations

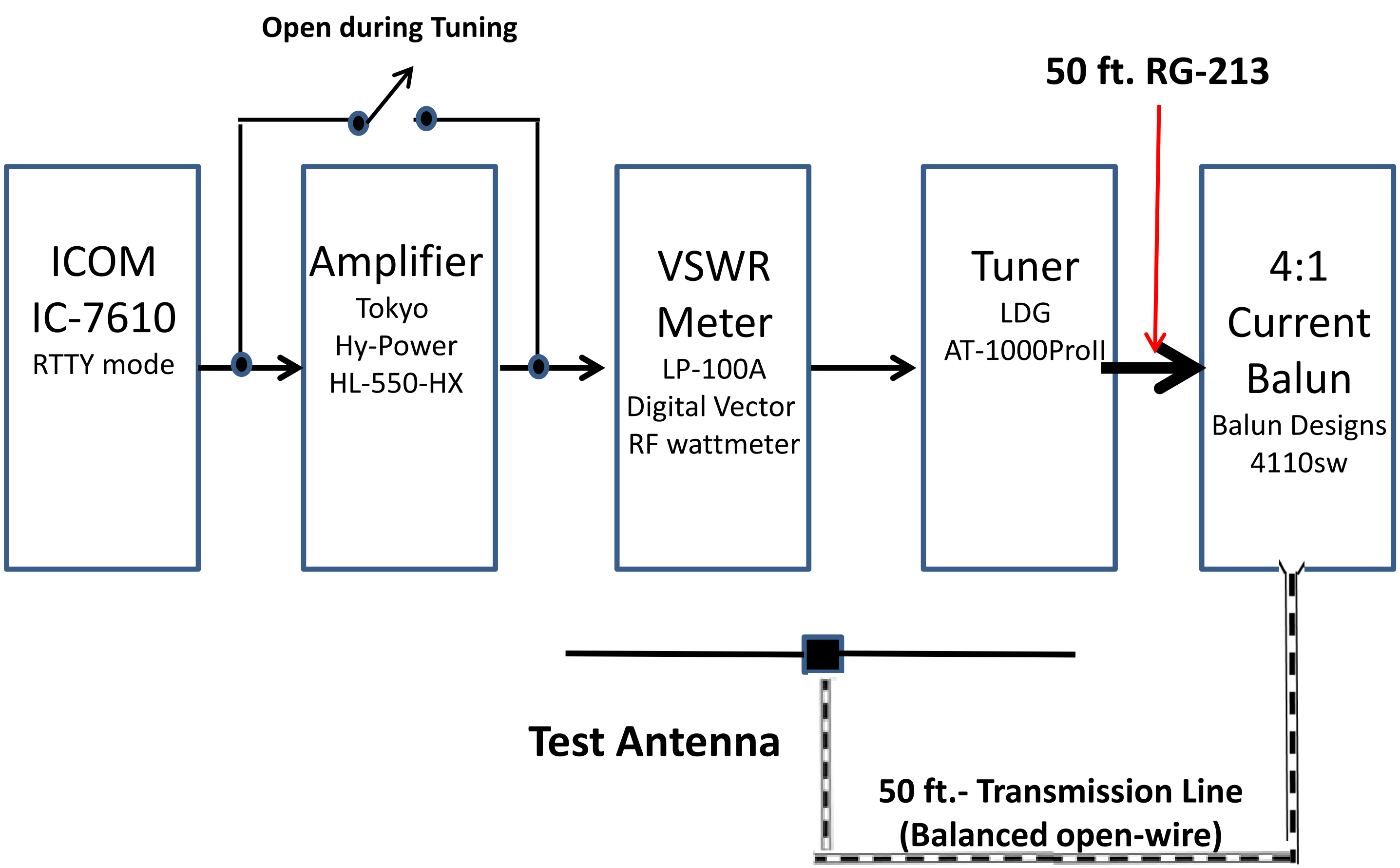
- HOA limitations at my location forced me to use my existing MARS horizontal long-wire support system. This support system runs between my chimney to an "endangered species" bird house. See pages 28 and 29
- Total available length – 100 ft.
- Height – 21 ft. horizontal
- Antenna heading is within 5˚ of magnetic North-South.
- The height of this test apparatus is not the optimum deployment height for long range. Best height would be horizontal from 35 – 40 ft.

Test Antenna Setup



Test Antenna Transmission Lines

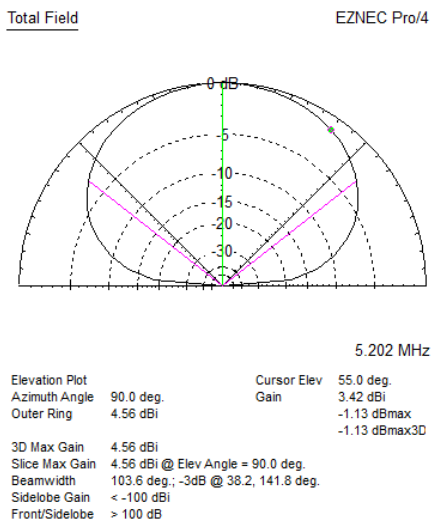
Block Diagram of Test Apparatus

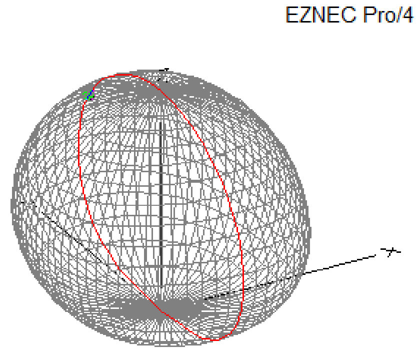


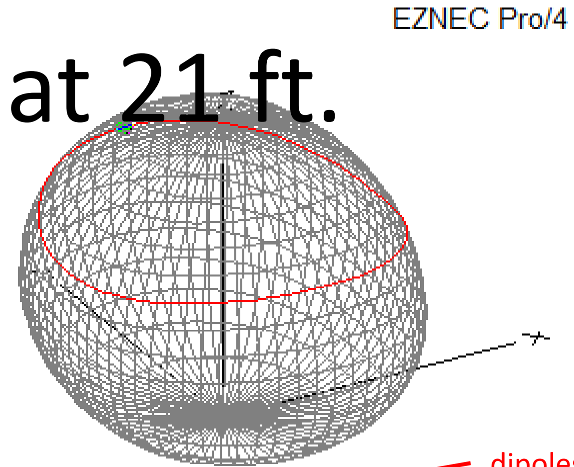
Army MARS Communication Validation Test - Cobra Ultralite Junior

- Date – 8 DEC 2025
- Time – 0100 UTC (7 PM)
- Net designation – M6A
- RI Traffic - #0428
- Frequency – 5.2MHz (CF=6 MHz)
- Transmit power – 350 watts
- Sent RRI to AAR6SM - #0294
- NCS – AAR6SM (location LA)
- Radio check with AAR6SM – Loud and Clear
- Addition RRI traffic received and decoded:
  - 5 RRI's from LA stations
  - 5 RRI's from TX stations
- Modeled Gain at 21 ft. height (horizontal) = 3.42 DBi

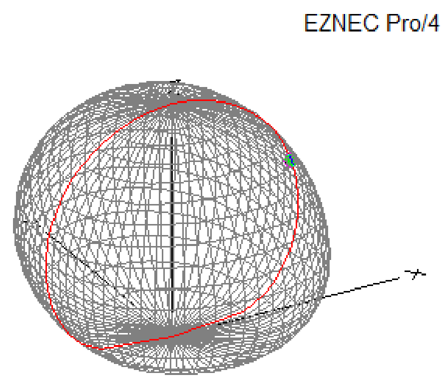
Azimuth & Elevation – 5.2 MHz Cobra Jr. Horizontal at 21 ft.

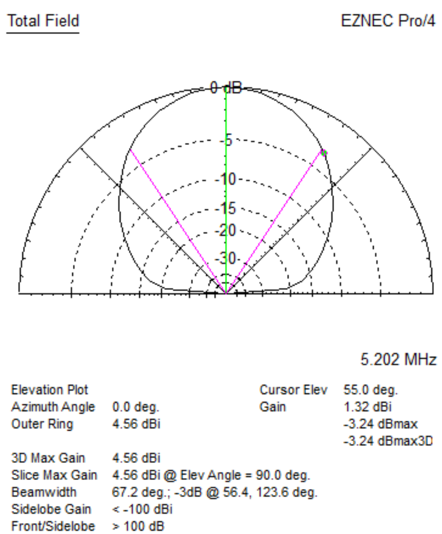


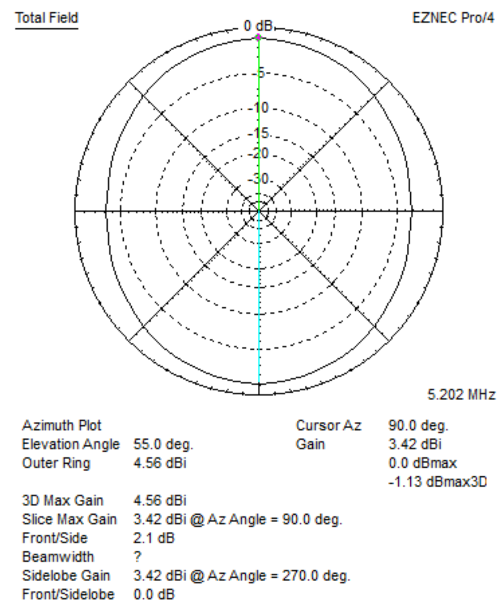




dipoles



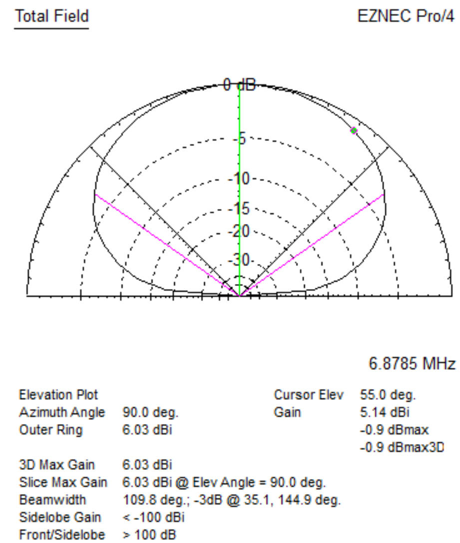


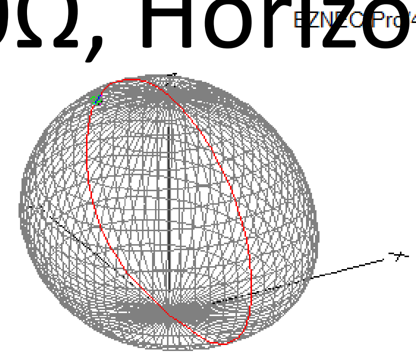


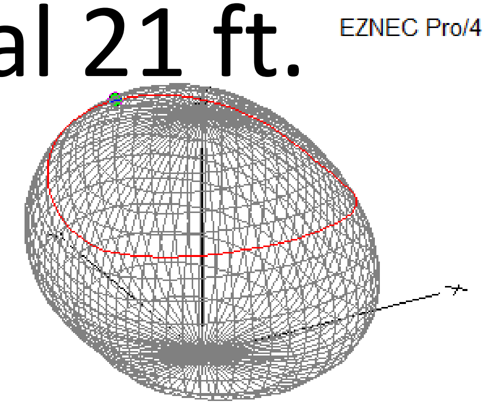
Army MARS Communication Validation Test – Netcom 66/44 450Ω LL Antenna

- Date – 9 DEC 2025
- Time – 1400 UTC
- Net designation – M6A
- RI Traffic - #0428
- Frequency – 6.9 MHz (CF=7 MHz)
- Transmit power – 350 watts
- NCS – Self (AAR6UK)
- Radio check with AAR6PI and AAR6CE (Loud and Clear)
- RRI traffic received and decoded:
  - 9 stations from TX and LA
- Modeled Gain at 21 ft. height, horizontal = 5.14 dBi

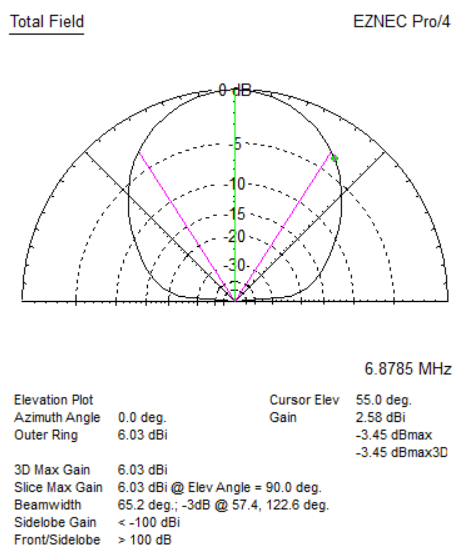
Azimuth & Elevation – 6.9 MHz
66/44 450Ω, Horizontal 21 ft.

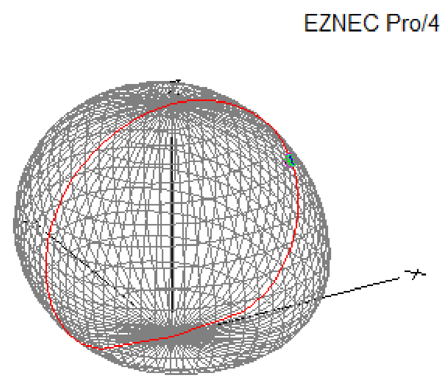


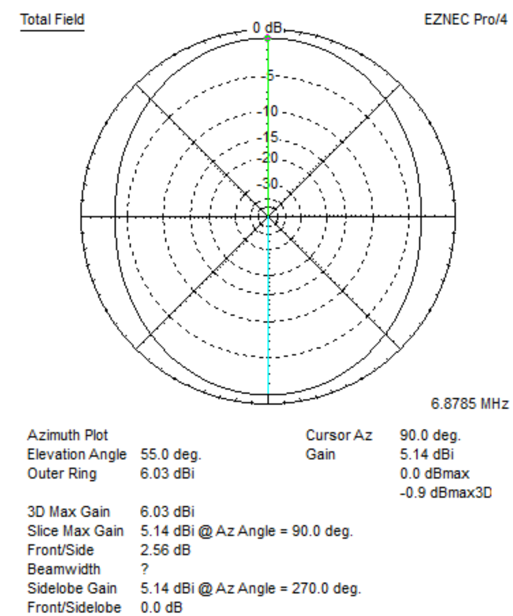




dipoles





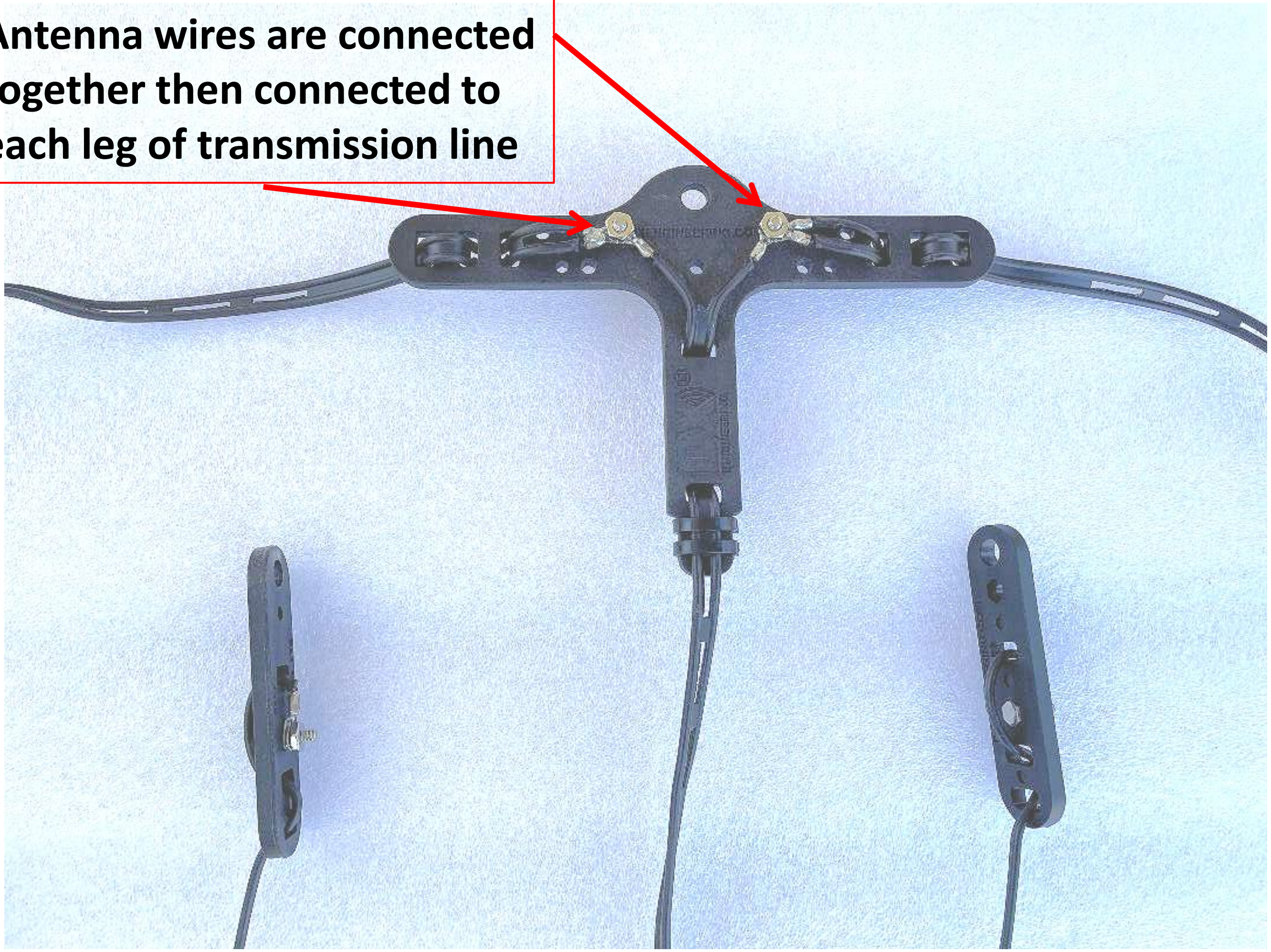


Additional Antennas Tested

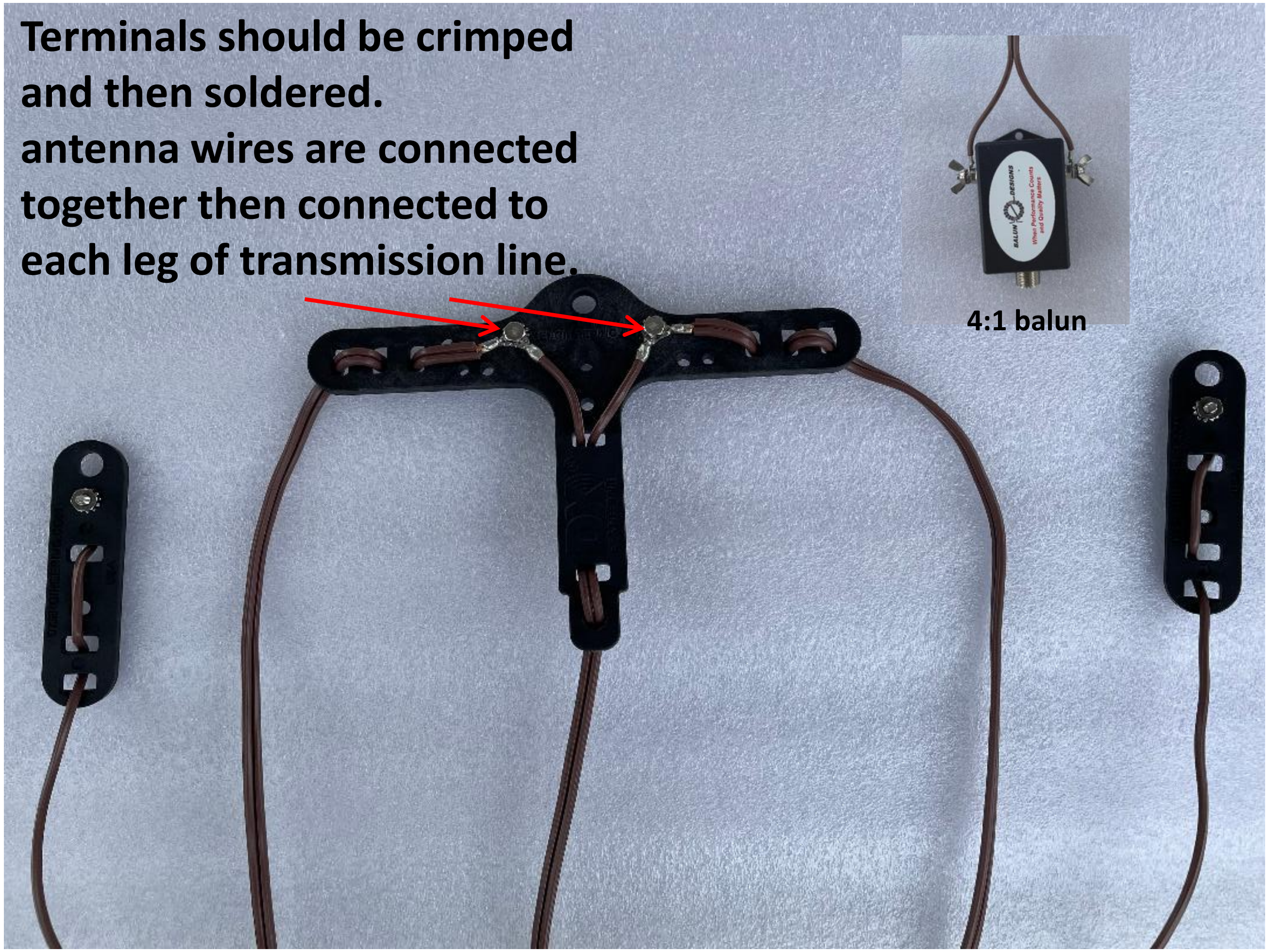
- Netcom 66/44 with 300Ω Ladder line – ruggedized implementation
- Netcom 66/44 using AWG #18 lamp cord – field expedient, constructed with Home Depo materials.

Assembly of 66/44 - 300Ω Antenna

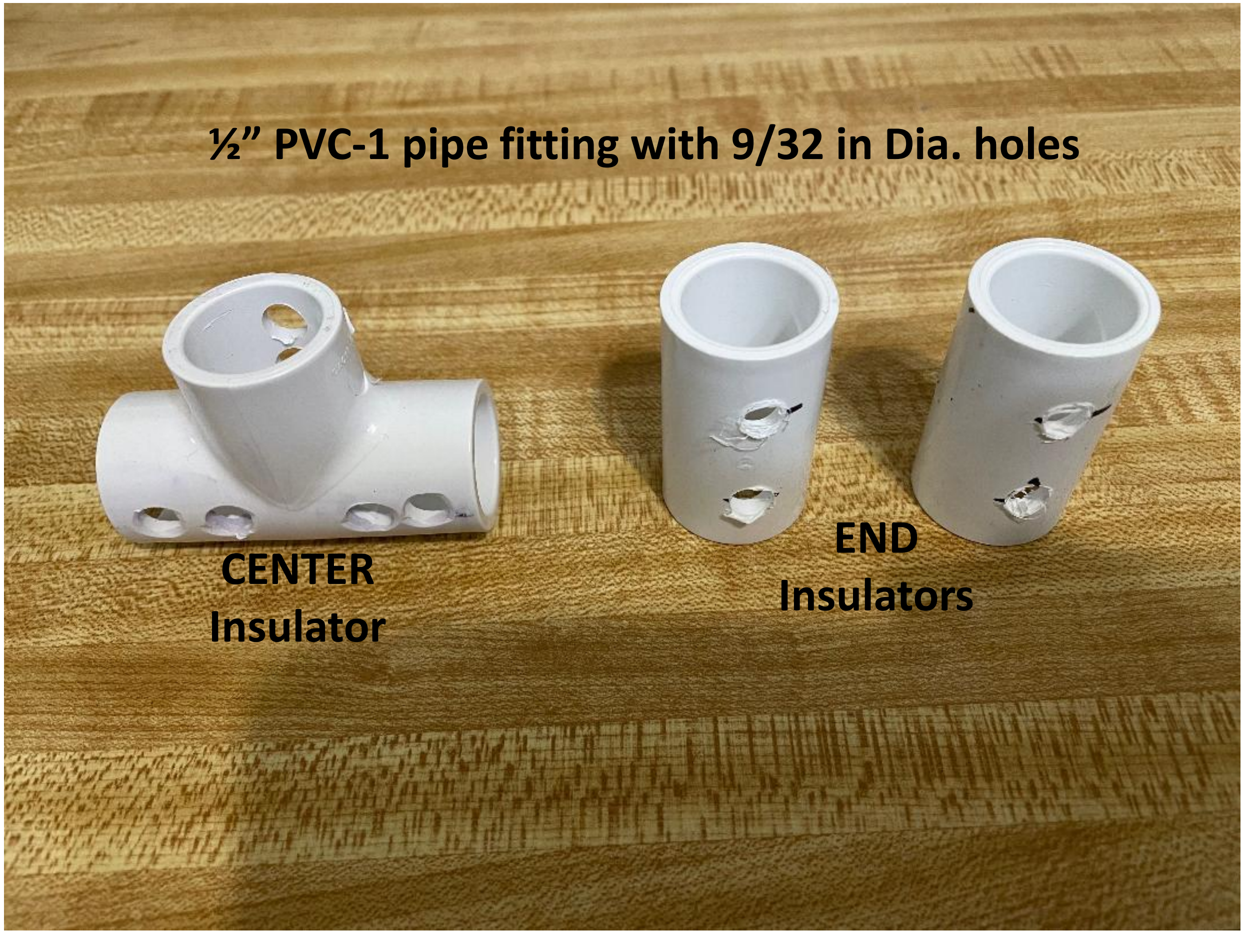
Terminals should be crimped and then soldered.
Antenna wires are connected together then connected to each leg of transmission line



Assembly of 66/44 Lamp Cord Antenna

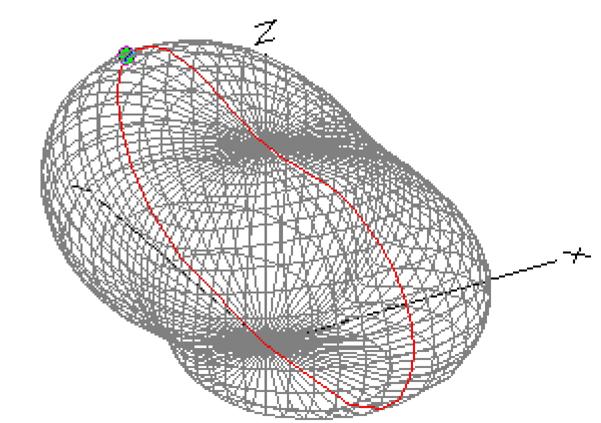


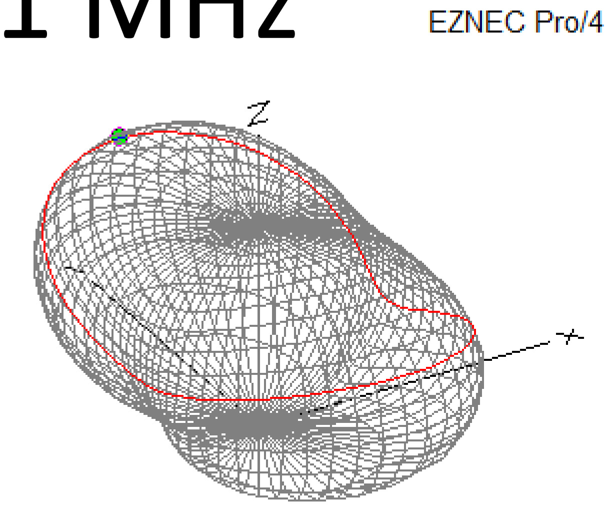
Alternate Center T and End Insulators (PVC pipe fittings)

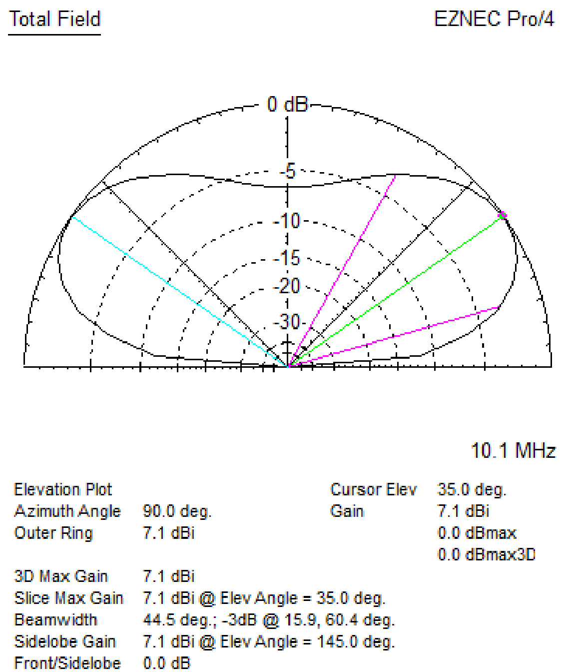


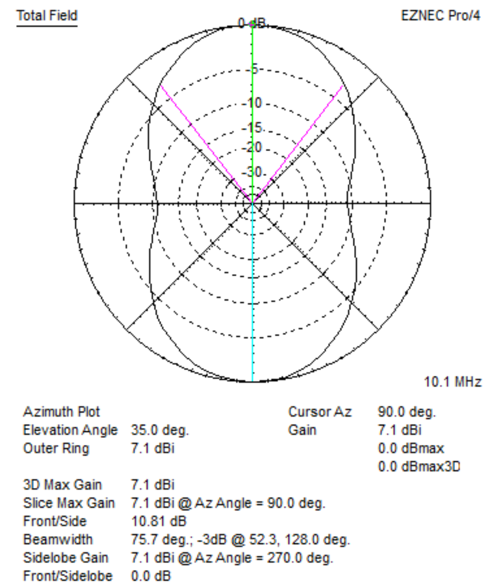
LONG-RANGE
EZNEC MODELS
HEIGHT – 40 FT. HORIZONTAL

Frequency 10.1 MHz

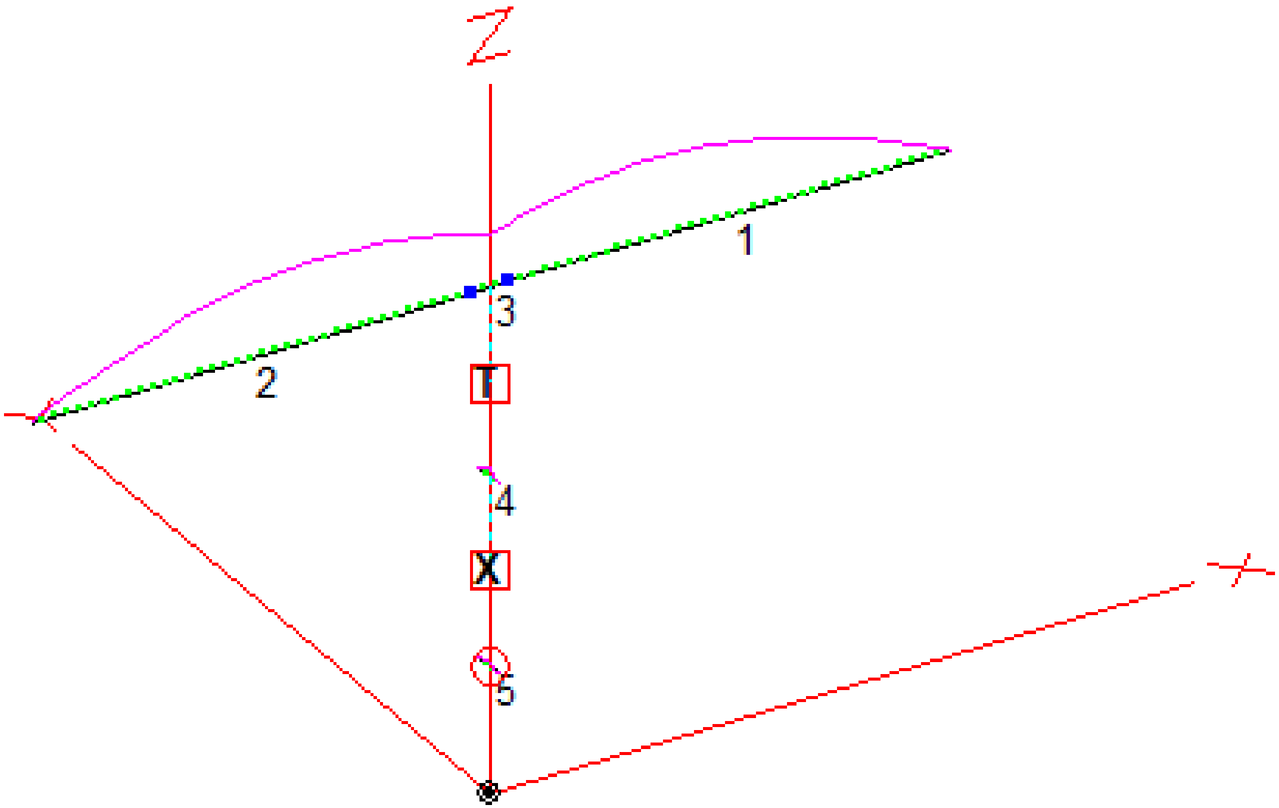




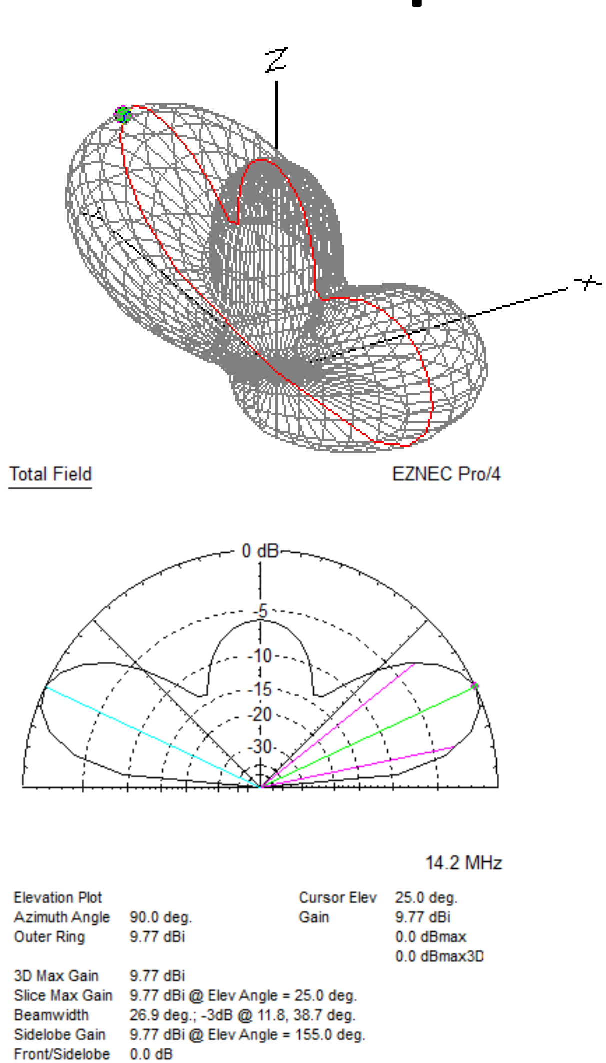


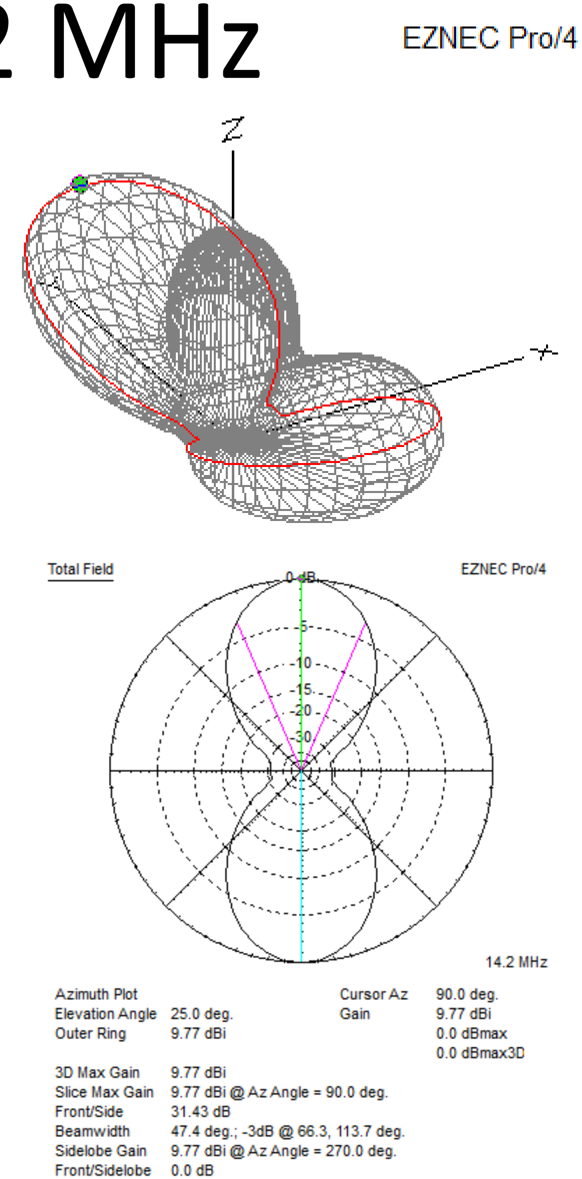


Current Distribution – 10.1 MHz

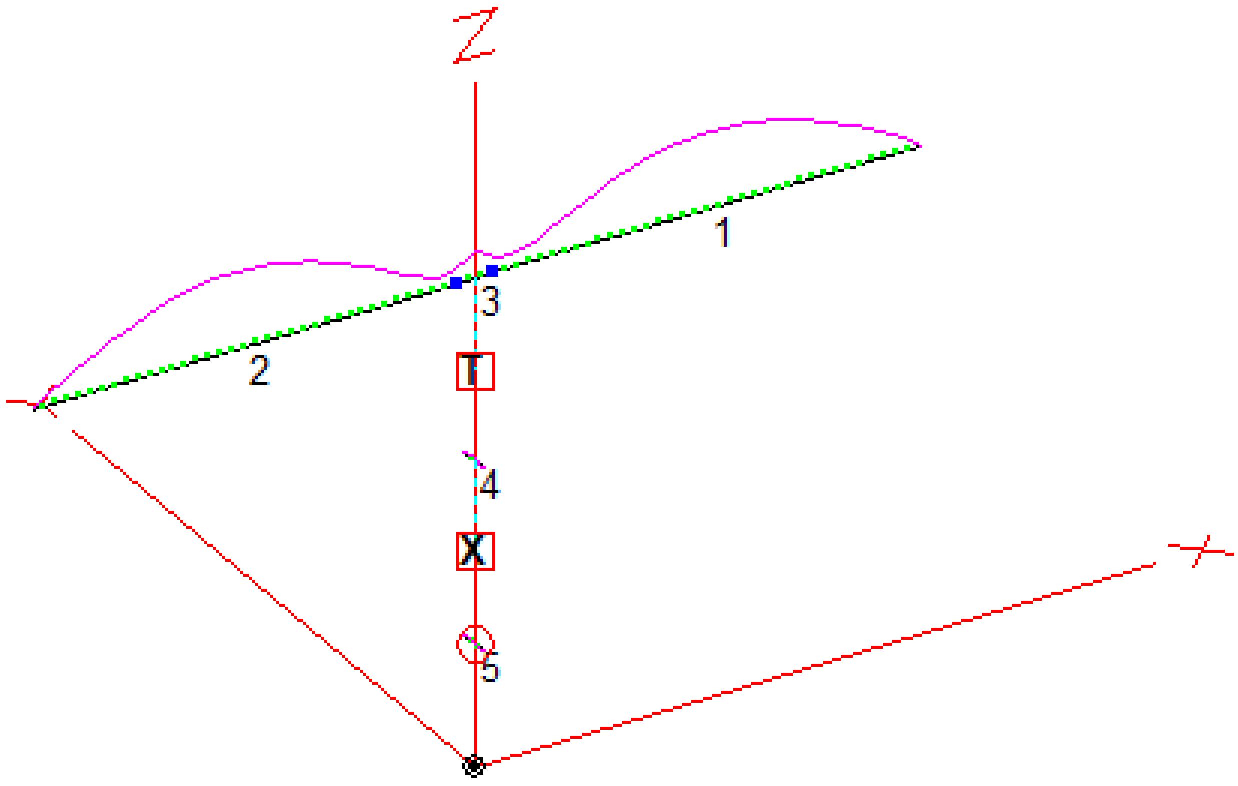


Frequency 14.2 MHz

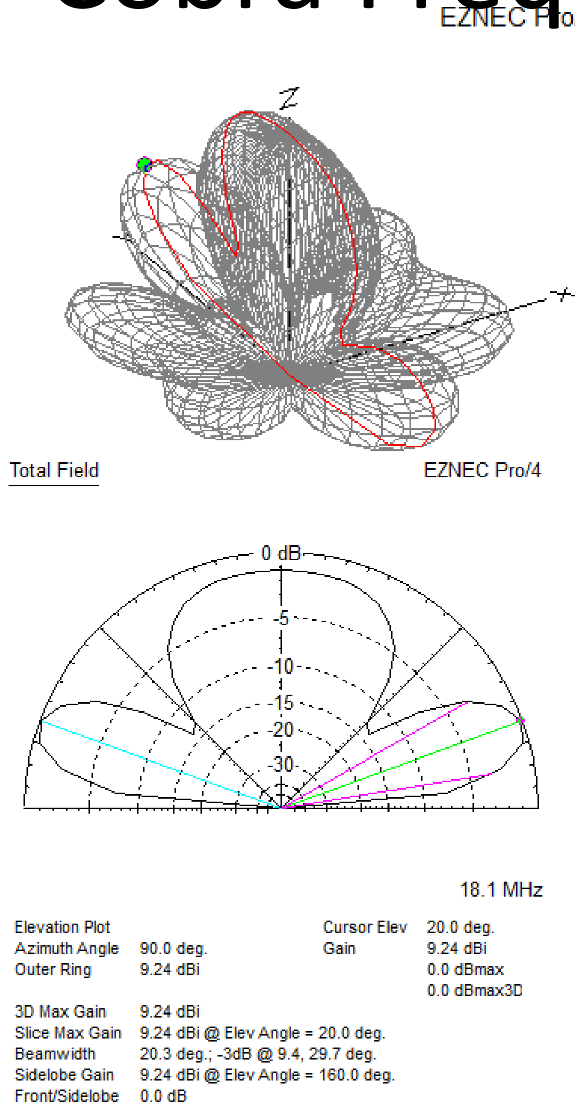


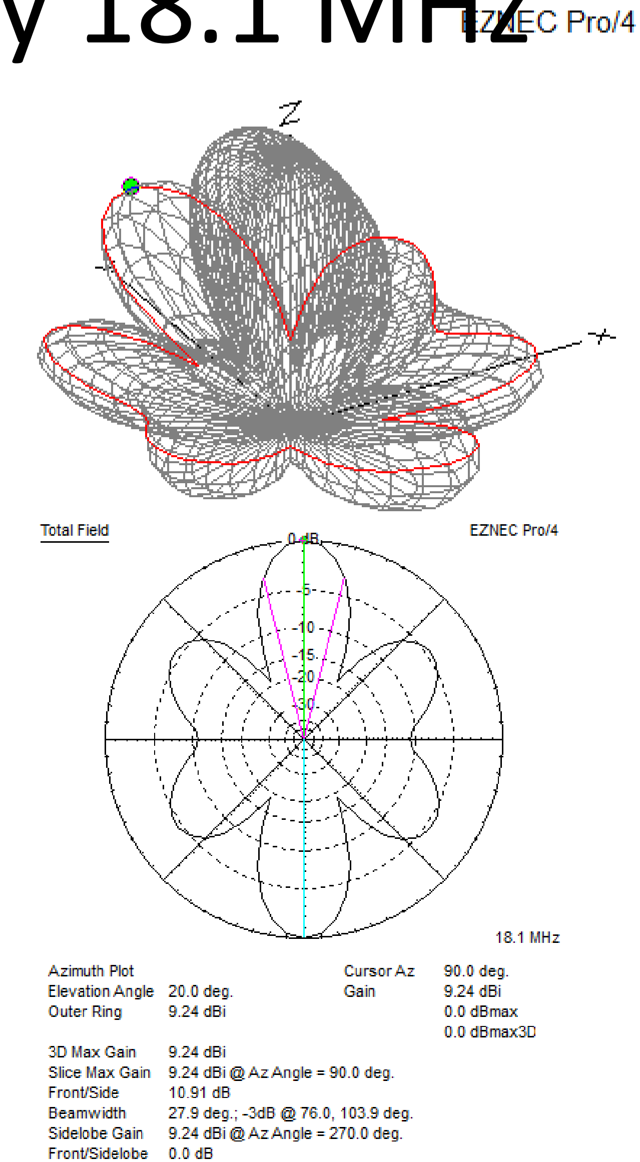


Current Distribution – 14.2 MHz

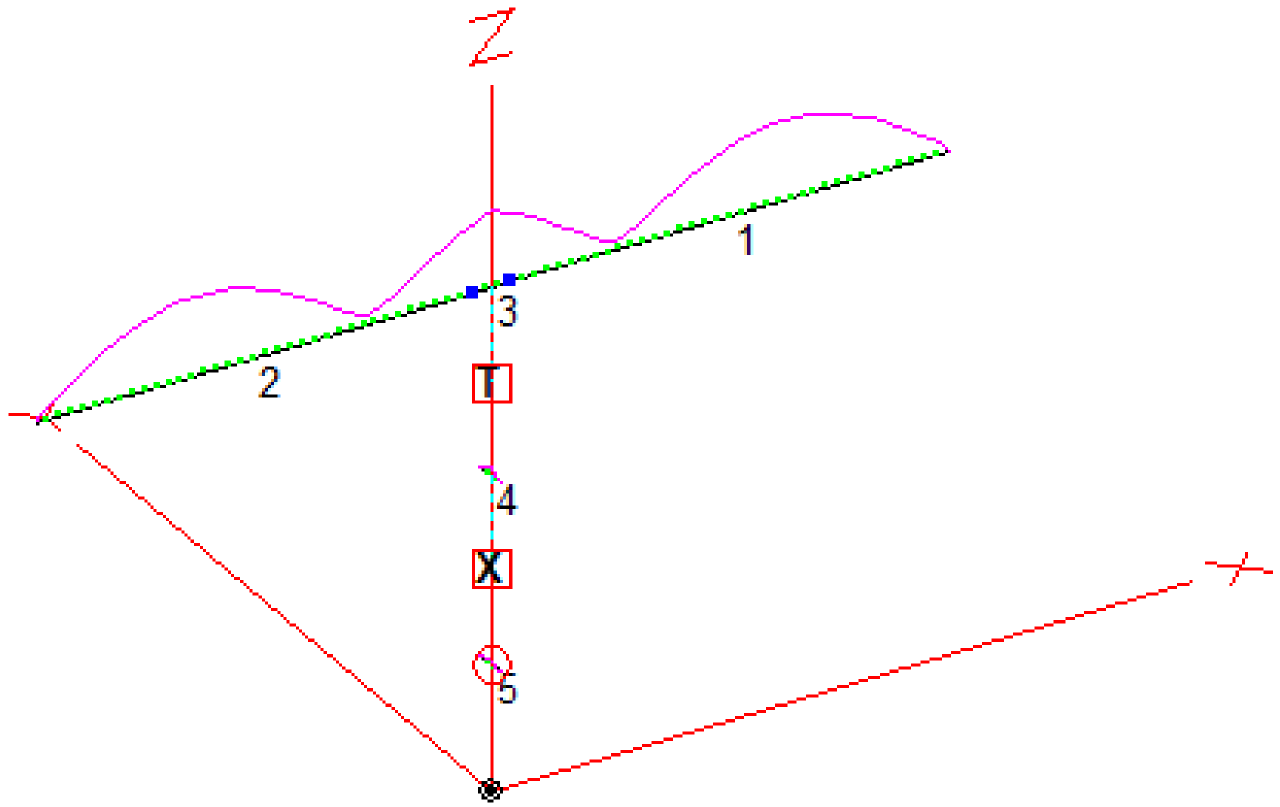


Cobra Frequency 18.1 MHz

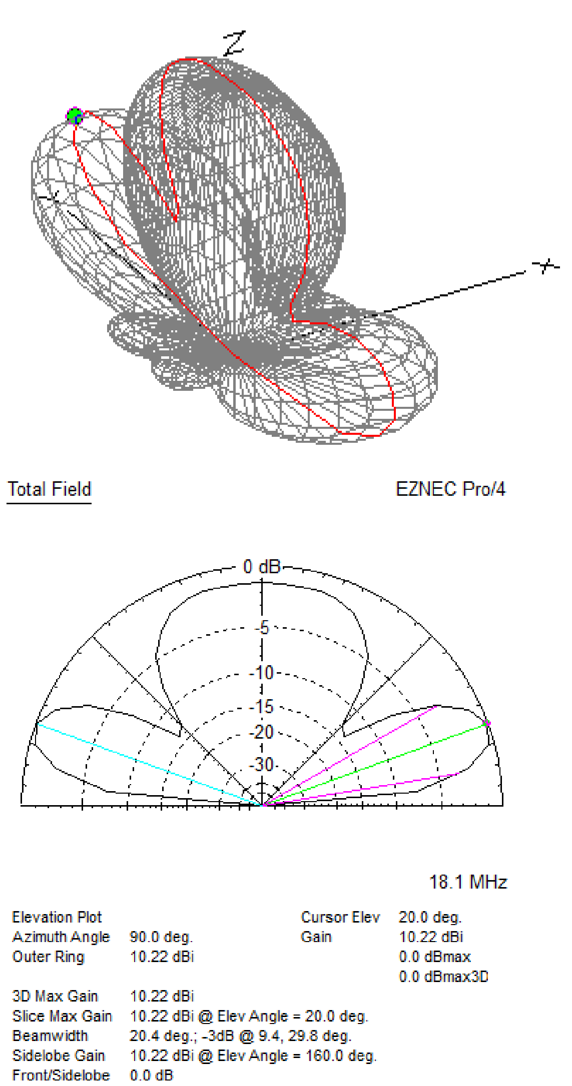


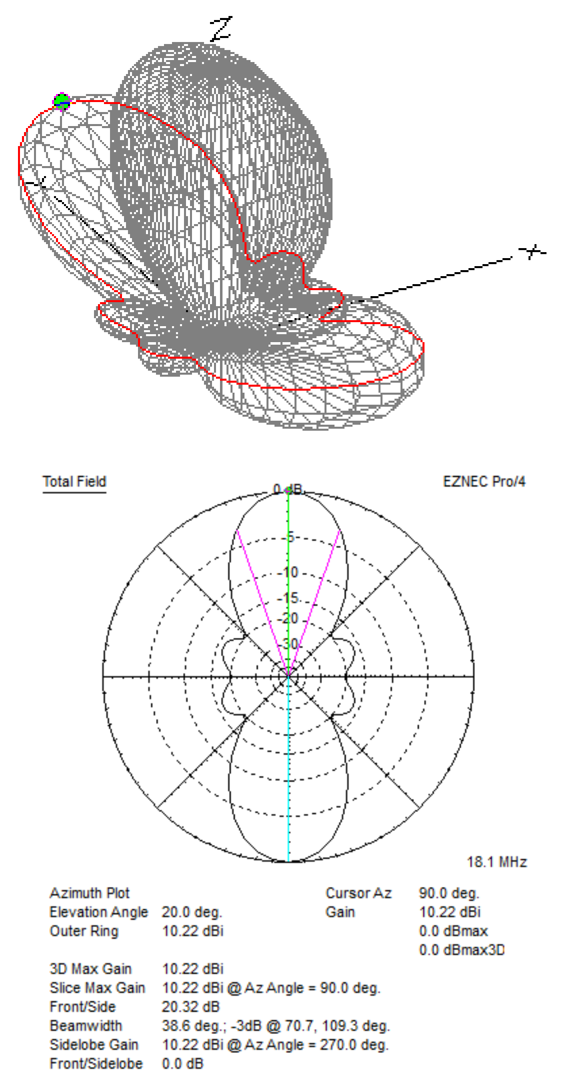


Cobra Current Distribution – 18.1 MHz

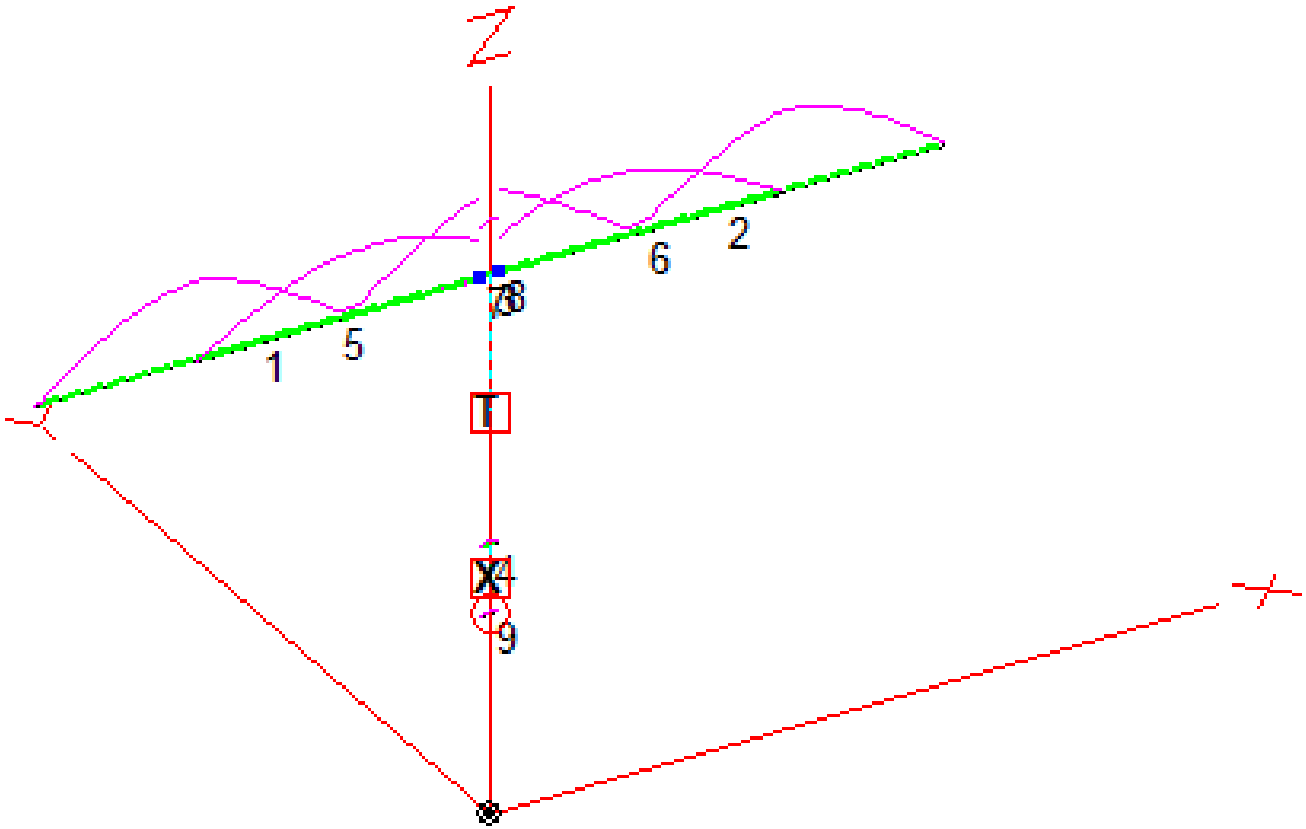


Netcom Frequency 18.1 MHz



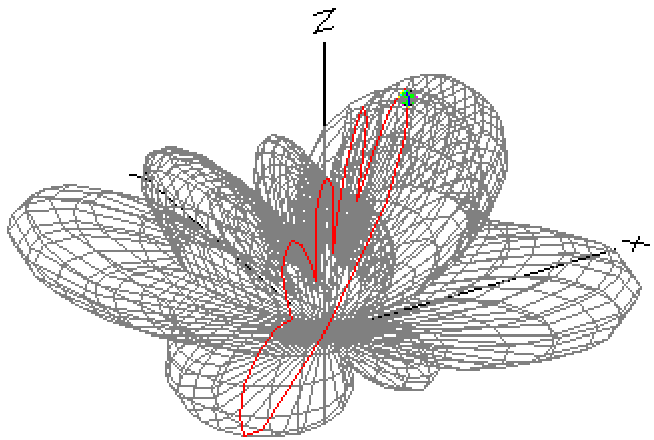


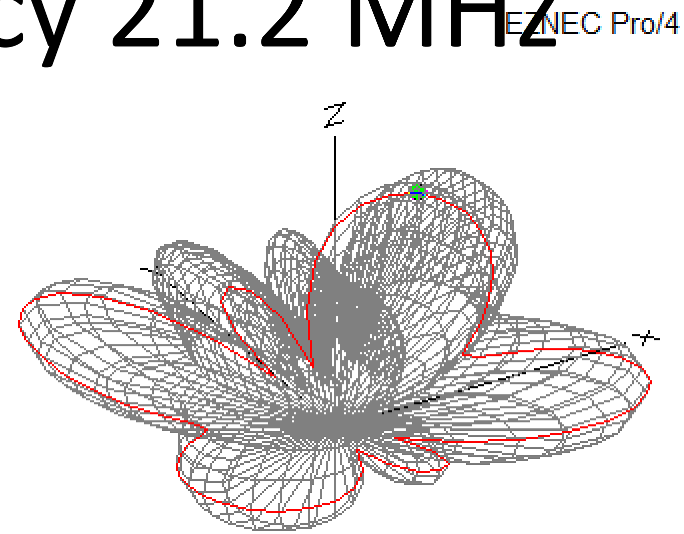
Netcom Current Distribution – 18.1 MHz

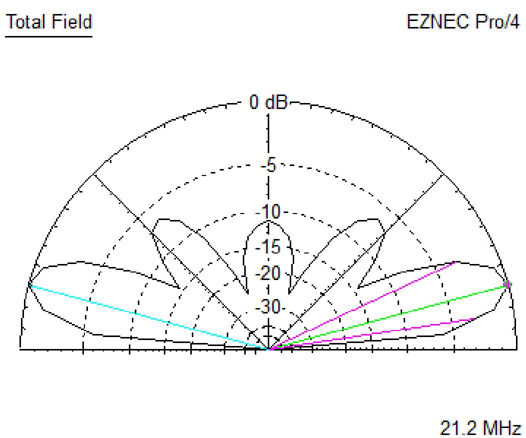


COBRA ANTENNA HAS SHIFTED TO END-FIRE DIRECTIVITY
NETCOM 66/44 STILL HAS BROADSIDE GAIN

Cobra Frequency 21.2 MHz



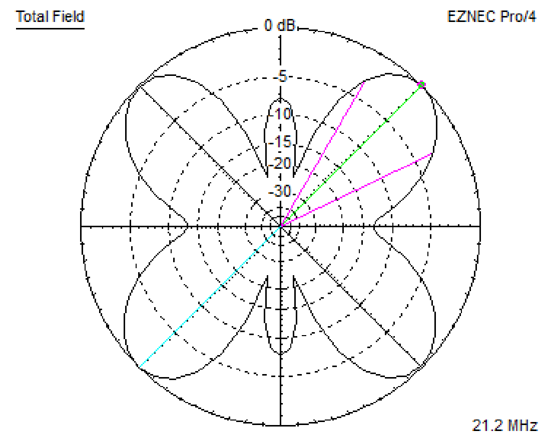




Elevation Plot
Azimuth Angle 45.0 deg.
Outer Ring 8.83 dBi

Cursor Elev 15.0 deg.
Gain 8.83 dBi
0.0 dBmax
0.0 dBmax3D

3D Max Gain 8.83 dBi
Slice Max Gain 8.83 dBi @ Elev Angle = 15.0 deg.
Beamwidth 16.5 deg.; -3dB @ 8.3, 24.8 deg.
Sidelobe Gain 8.83 dBi @ Elev Angle = 165.0 deg.
Front/Sidelobe 0.0 dB

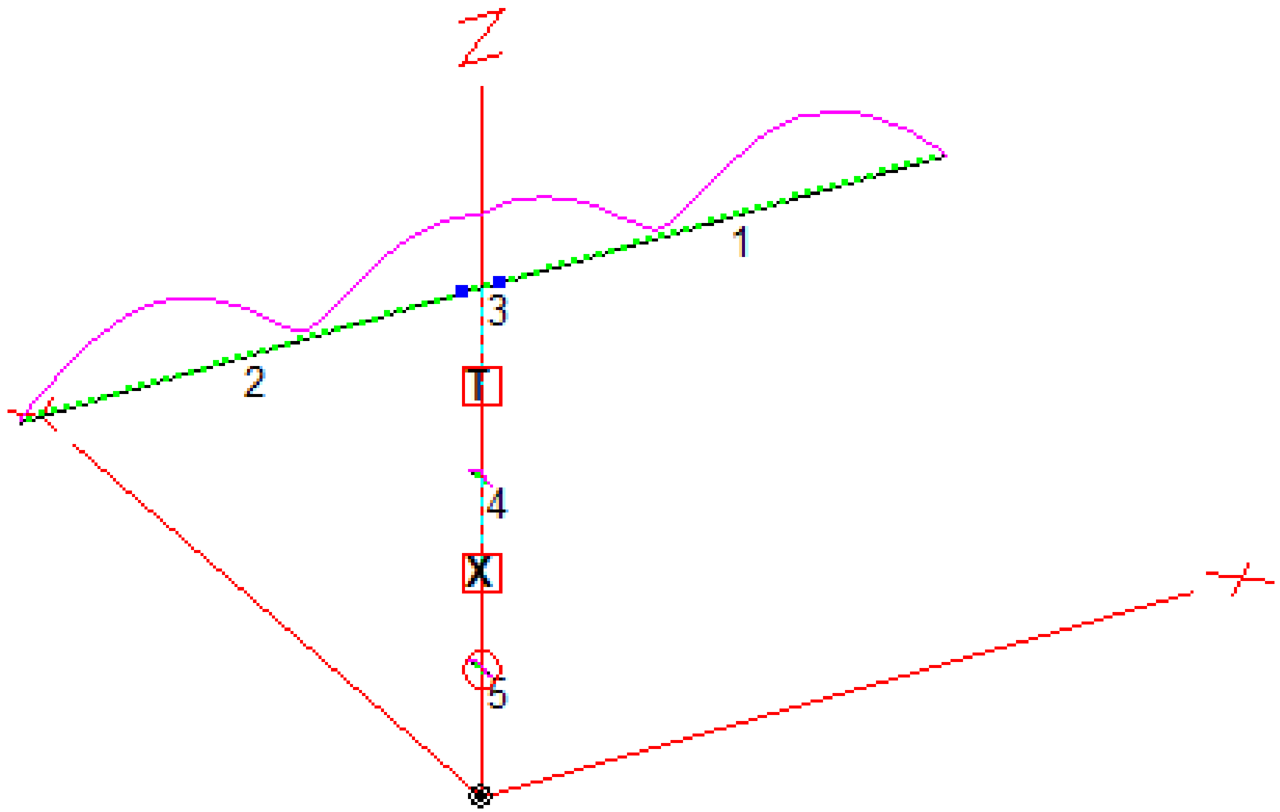


Azimuth Plot
Elevation Angle 15.0 deg.
Outer Ring 8.83 dBi

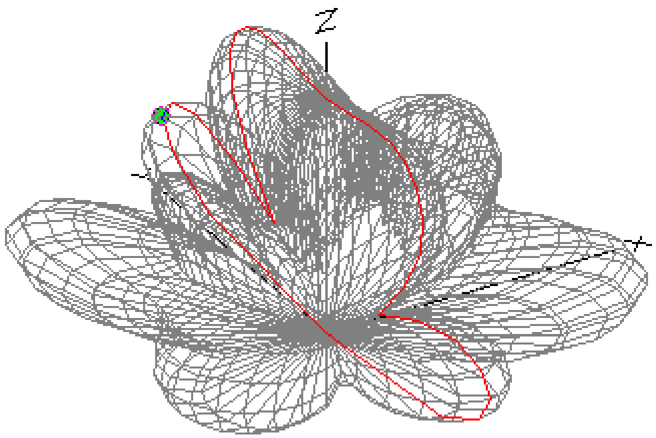
Cursor Az 45.0 deg.
Gain 8.83 dBi
0.0 dBmax
0.0 dBmax3D

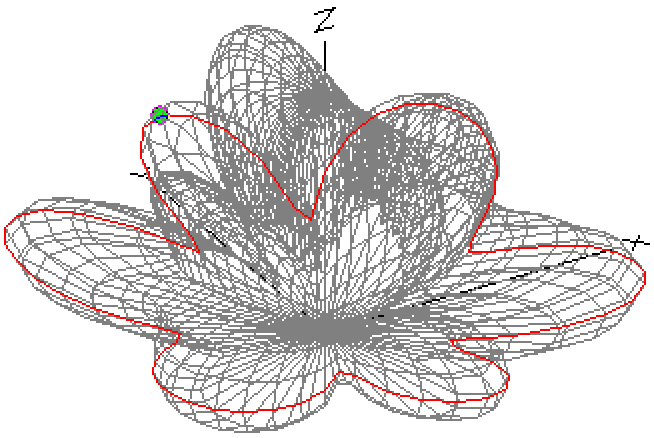
3D Max Gain 8.83 dBi
Slice Max Gain 8.83 dBi @ Az Angle = 45.0 deg.
Front/Side 0.1 dB
Beamwidth 34.4 deg.; -3dB @ 25.5, 59.9 deg.
Sidelobe Gain 8.83 dBi @ Az Angle = 225.0 deg.
Front/Sidelobe 0.0 dB

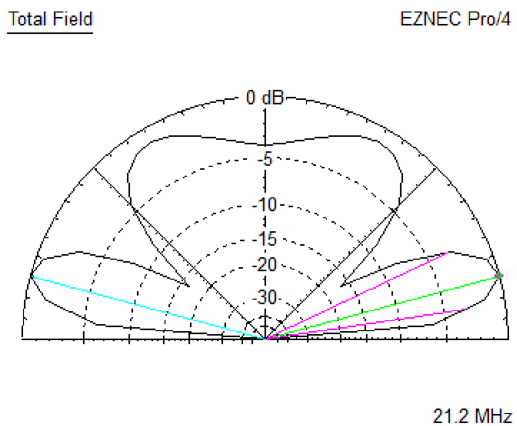
Cobra Current Distribution – 21.2 MHz



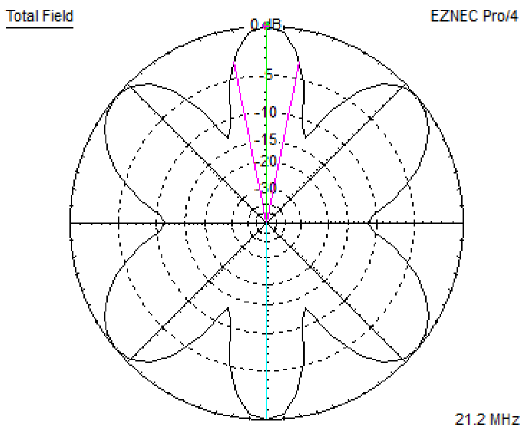
Netcom 66/44 Frequency 21.2 MHz





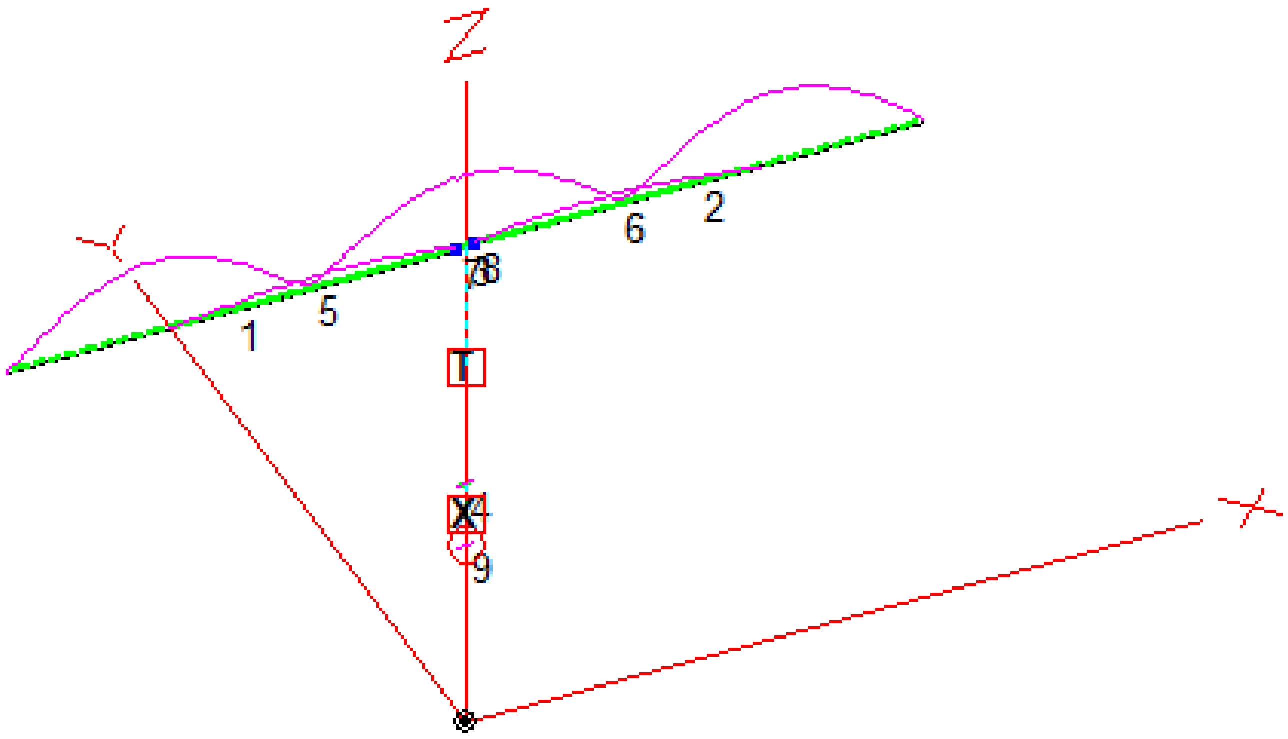


Elevation Plot		Cursor Elev	15.0 deg.
Azimuth Angle	90.0 deg.	Gain	7.77 dBi
Outer Ring	7.77 dBi		0.0 dBmax
			0.0 dBmax3D
3D Max Gain	7.77 dBi		
Slice Max Gain	7.77 dBi @ Elev Angle = 15.0 deg.		
Beamwidth	16.8 deg.; -3dB @ 8.4, 25.2 deg.		
Sidelobe Gain	7.77 dBi @ Elev Angle = 165.0 deg.		
Front/Sidelobe	0.0 dB		



Azimuth Plot		Cursor Az	90.0 deg.
Elevation Angle	15.0 deg.	Gain	7.77 dBi
Outer Ring	7.77 dBi		0.0 dBmax
			0.0 dBmax3D
3D Max Gain	7.77 dBi		
Slice Max Gain	7.77 dBi @ Az Angle = 90.0 deg.		
Front/Side	11.47 dB		
Beamwidth	22.6 deg.; -3dB @ 78.7, 101.3 deg.		
Sidelobe Gain	7.77 dBi @ Az Angle = 270.0 deg.		
Front/Sidelobe	0.0 dB		

Netcom Current Distribution – 21.2 MHz



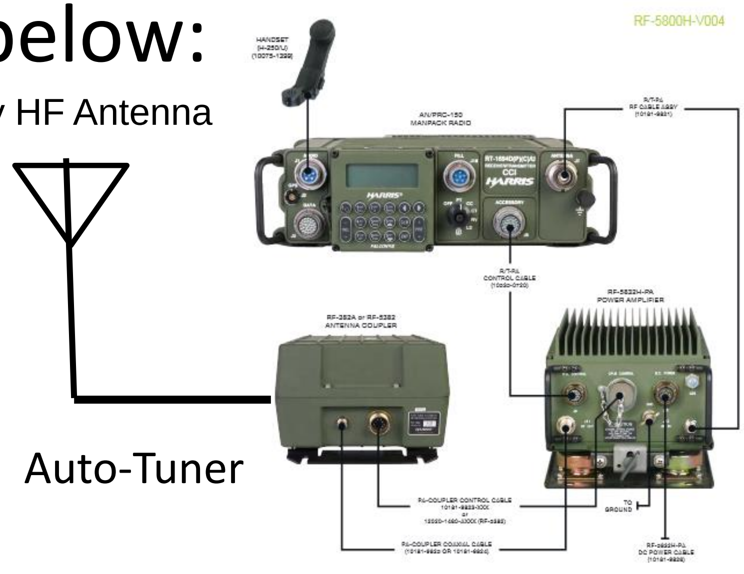
ANTENNA TUNING

Antenna Tuning Challenge

- Broadband HF Antennas will have wildly varying Impedances that cannot be resolved to a low SWR solution with the internal tuners found on modern HF rigs (3:1 maximum).
- A wide-range, external tuner must be employed to lower SWR to less than 2:1 so that rig will deliver full power.

External Antenna Tuners Options

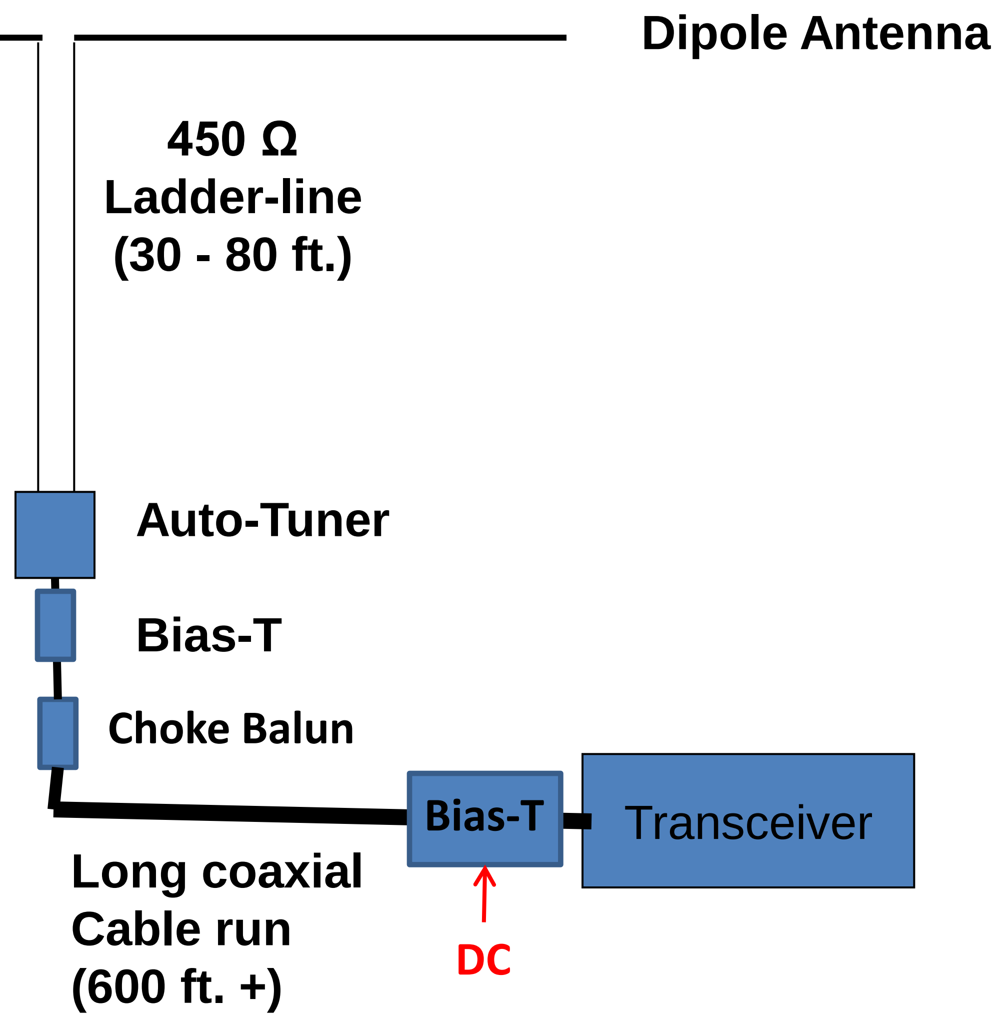
- Tuner located at rig
- Tuner located at antenna – preferred method for Marine and Military HF antenna systems as shown below:



Remote Tuner at Mast Base

Chameleon CHA URT1
(Built-in Bias-T's)

CG Antenna Ltd. - CG-3000
(Needs external Bias-T's)



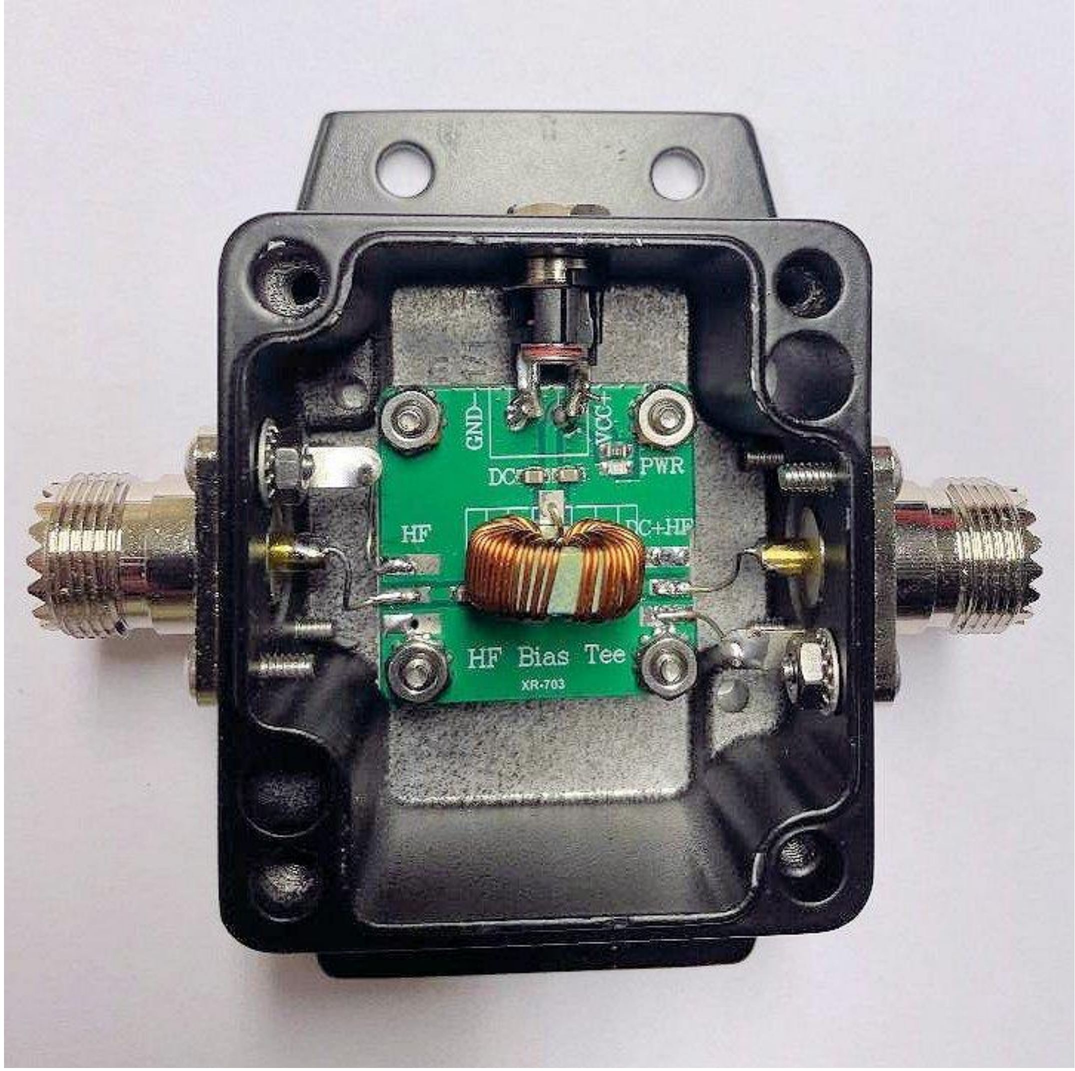
VSWR Test Results – Height 21 ft. CG Antenna Ltd. CG-3000

Freq. MHz	VSWR - LL 66/44 dipole	VSWR Cobra Jr.	Comments
2.2	2.27	1.91	
3.3	1.23	no solution	Tuner hunted for solution without success
4.0	1.12	1.05	
5.2	1.26	1.13	
6.9	1.16	1.05	
7.5	1.12	1.15	
8.0	1.19	1.26	
9.3	1.45	1.35	
11.5	1.33	1.51	
13.5	1.35	1.24	
14.48	1.82	1.52	

Bias-T Availability Problem

- When using a remote HF auto-tuner, it is convenient to send both RF and DC power through a single coaxial cable using Bias-T's at each end of the transmission line.
- The two available Bias-T's, shown below, are **no longer available**.

Solution: W5IFQ Bias-T

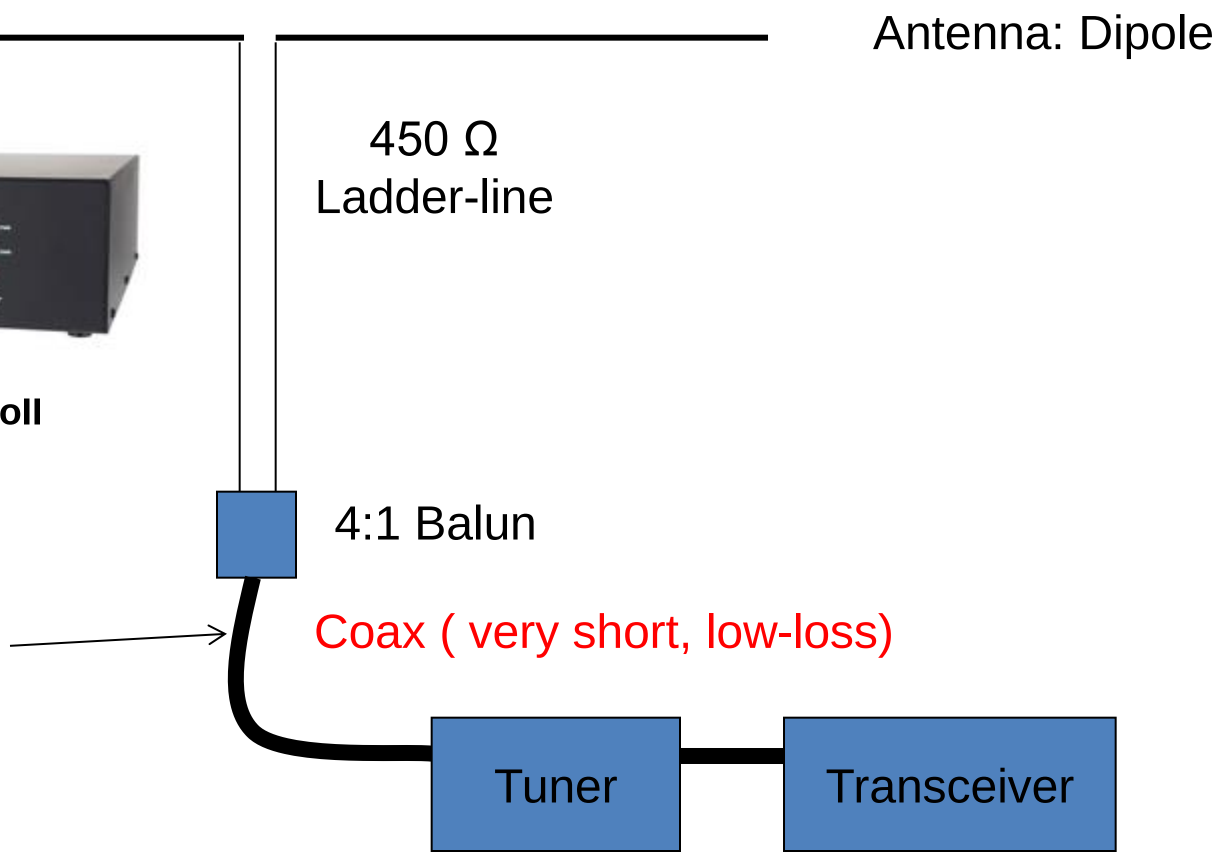


Remote Tuner Comments

- Bias-T's can be used to send both DC power and RF to the remote tuner through the single coaxial cable. (Very convenient!)
- Lightning and EMP mitigation must be implemented to protect tuner.
- Plastic cased tuners must be protected from solar UV.
- Contact me for design details.

Tuner at Rig

LDG-AT 1000ProII



High SWR

VSWR Test Results
Height 21 ft. LDG-AT-1000ProII Tuner

Freq. MHz	Cobra Jr.	LL 66/44 450
2.2	5.07	3.38
3.3	1.79	1.22
4.0	1.12	2.14
5.2	1.6	1.41
6.9	1.25	1.5
7.5	1.13	1.25
8.0	1.17	1.55
9.3	1.46	1.29
11.5	1.11	1.35
13.5	1.3	1.34
14.48	1.52	1.16

Conclusions

- A NVIS antenna must maximize Elevation gain vertically. This is accomplished by operating at a vertical height of .25λ.
- NVIS operating frequencies must be slightly below local Critical Frequencies of 75m, 60m and 40m (3.8, 5.3, 7.2 MHz).
- As the same dipole height exceeds 0.5λ, the horizontal azimuthal shifts to long-range characteristics. This will automatically occur as operating frequency is moved up to long-range frequencies of 30m, 20m and 17m (10.1, 14 and 18 MHz).
- The overall length of the dipole should not exceed 1λ to minimize horizontal azimuthal variation.
- Additional modeling shows that heights of 30-40 ft. horizontal are good and easily achieved with available telescoping masts.
- External tuners must be used to tune the antenna to 50 Ω to maximize RF power transfer from the radio to the antenna.

Questions?

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W5IFQ

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W5IFQ@att.net