JCSE HF Antenna Analysis

Noble Skywave 2024

Notes

These tests were conducted as part of the Joint Communications Support Element's (JCSE) preparation for Noble Skywave 2024 (NS24).

During Noble Skywave 2024 JCSE emerged victorious, claiming **FIRST PLACE** in the international 0-150 watt power category and **FIRST PLACE** against all power categories in the 3G group challenge.

JCSE also outperformed all of the teams in the international 150-400 watt category and took second overall against the 400+ watt category scoring within 5% of the top 400+ watt team at a fixed and established radio site.

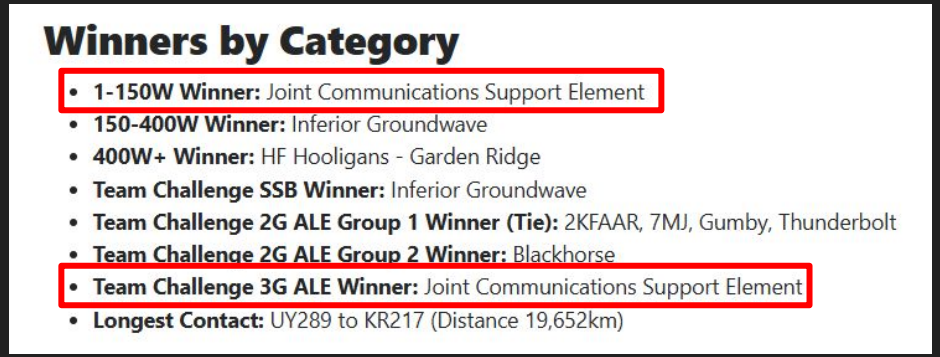
The entire JCSE NS24 site was constructed explicitly for the exercise, all antennas were built during set up and are not permanently installed.

Notes

JCSE HF Victories:

QRPX 2022 - 1st Place
NS22 - 2nd Place (Low Power)
QRPX 2023 - 1st Place
NS23 - 1st Place (Low Power), 3rd Overall
QRPX 2024 - 1st Place
NS24 - 1st Place (Low Power), 2nd Overall

Noble Skywave 2024 Results



Winners by Category

- **1-150W Winner:** Joint Communications Support Element
- **150-400W Winner:** Inferior Groundwave
- **400W+ Winner:** HF Hooligans - Garden Ridge
- **Team Challenge SSB Winner:** Inferior Groundwave
- **Team Challenge 2G ALE Group 1 Winner (Tie):** 2KFAAR, 7MJ, Gumby, Thunderbolt
- **Team Challenge 2G ALE Group 2 Winner:** Blackhorse
- **Team Challenge 3G ALE Winner:** Joint Communications Support Element
- **Longest Contact:** UY289 to KR217 (Distance 19,652km)

JCSE always competes in a tactical environment and never uses fixed infrastructure for HF competitions or training.

Notes

All tests conducted at 5 Watts using FT8 unless stated otherwise

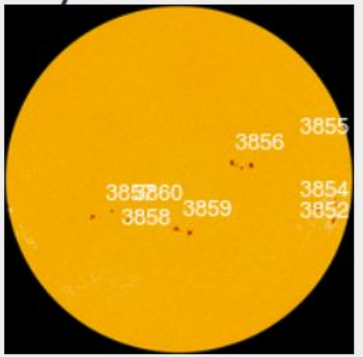
Results from one time of day are not representative of other times throughout the day

All results for these tests other than the 500’ loop were recorded from 0930-1110 local time on 18 October 2024

Solar wind
speed: **390.7** km/sec
density: **8.29** protons/cm^3
more data: ACE, DSCOVR
Updated: Today at 1147 UT

X-ray Solar Flares
6-hr max: **M4** 1938 UT Oct18
24-hr: **M4** 1938 UT Oct18
explanation | more data
Updated: Today at: 2350 UT

Daily Sun: 18 Oct 24



Expand: labels | no labels | Carrington

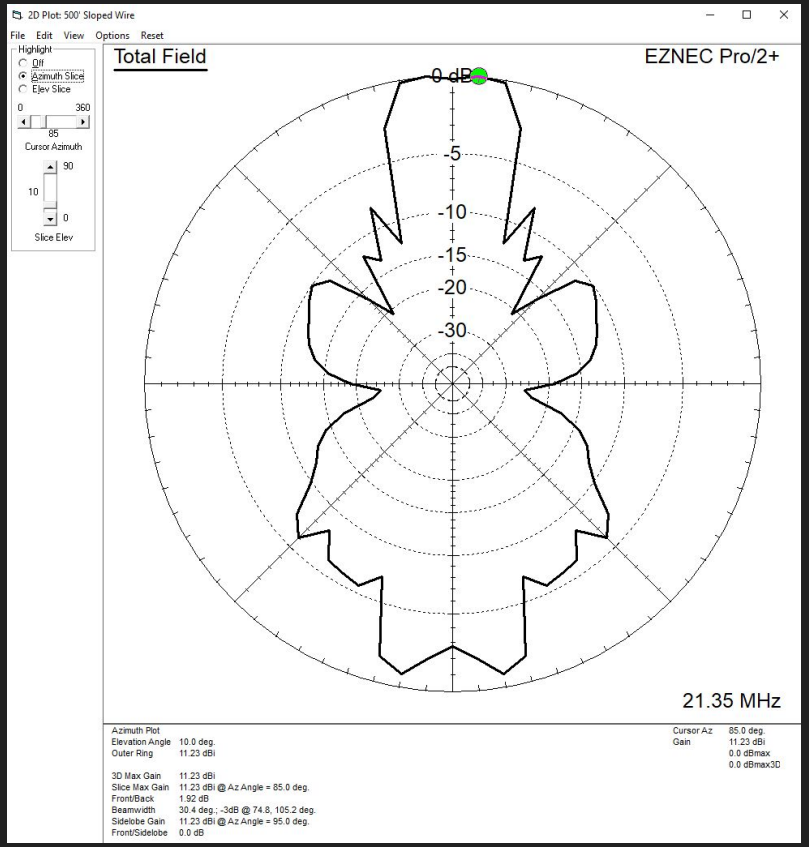
Sunspot 3856 has a delta-class magnetic field that harbors energy for X-class solar flares. Credit: SDO/HMI

Sunspot number: 146
What is the sunspot number?
Updated 18 Oct 2024

Antenna Overview

Understanding Reception Reports

- Directional antennas often thought of as unidirectional
- Reality is more complicated, many lobes exist other than the main lobe
- Propagation off of side lobes is always present, though weaker than the main lobe
- Very sensitive receivers will receive signals transmitted off of side lobes



Understanding VOACAP Charts

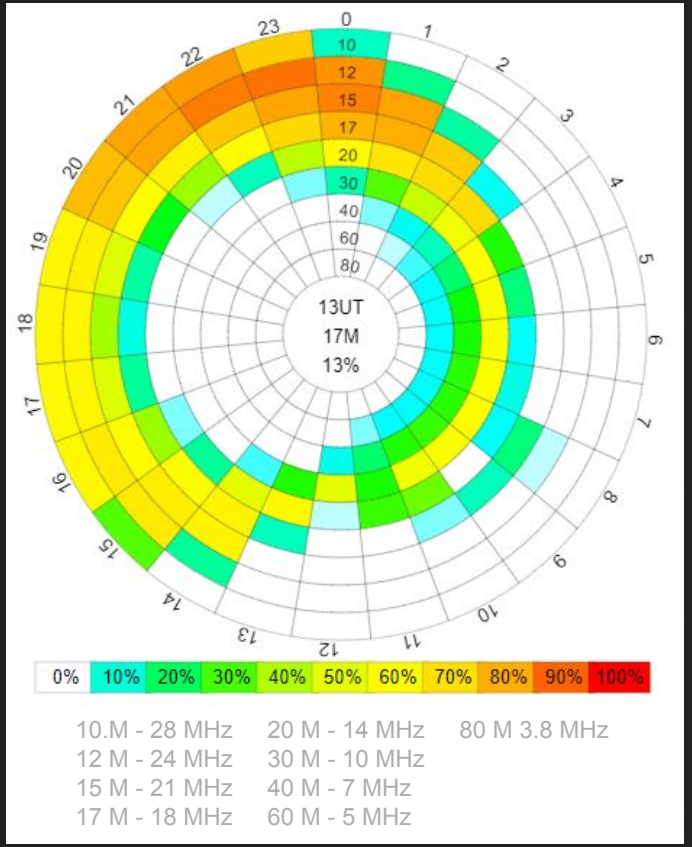
Circumference is Zulu/UTC time.

Vertical axis is wavelength.

Color represents the percentage of days in a given month that the Maximum Usable Frequency (MUF) will be above the given frequency during that time period.

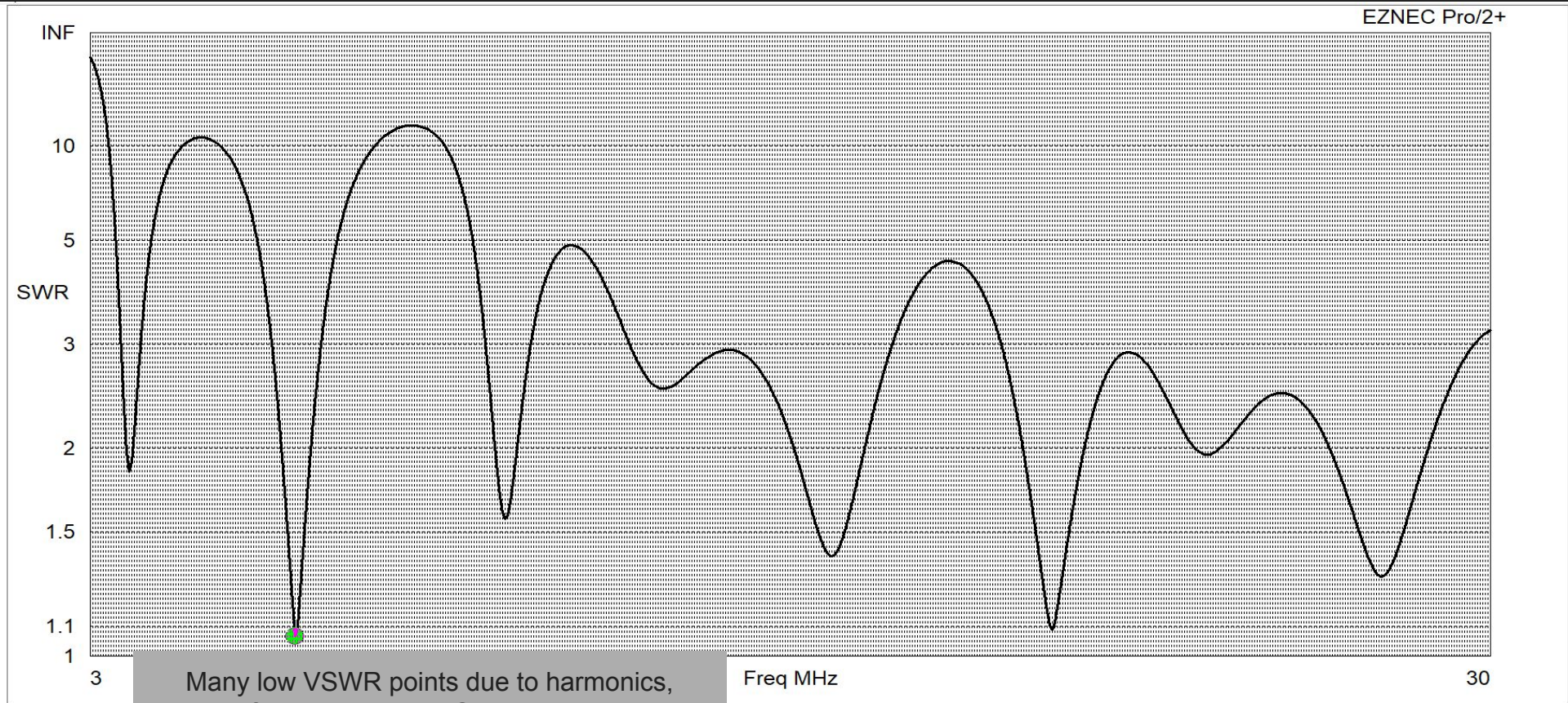
Bottom line: Red and orange are good, blue and green are bad.

Example: According to the chart the MUF between the selected locations on our selected day has roughly a 10% of being greater than 24 MHz (12 m wavelength) at 1400 zulu. We are relatively unlikely to be successful using a frequency above 24 MHz at that date and time.



286’ Delta Loop

286’ Loop VSWR (Model)

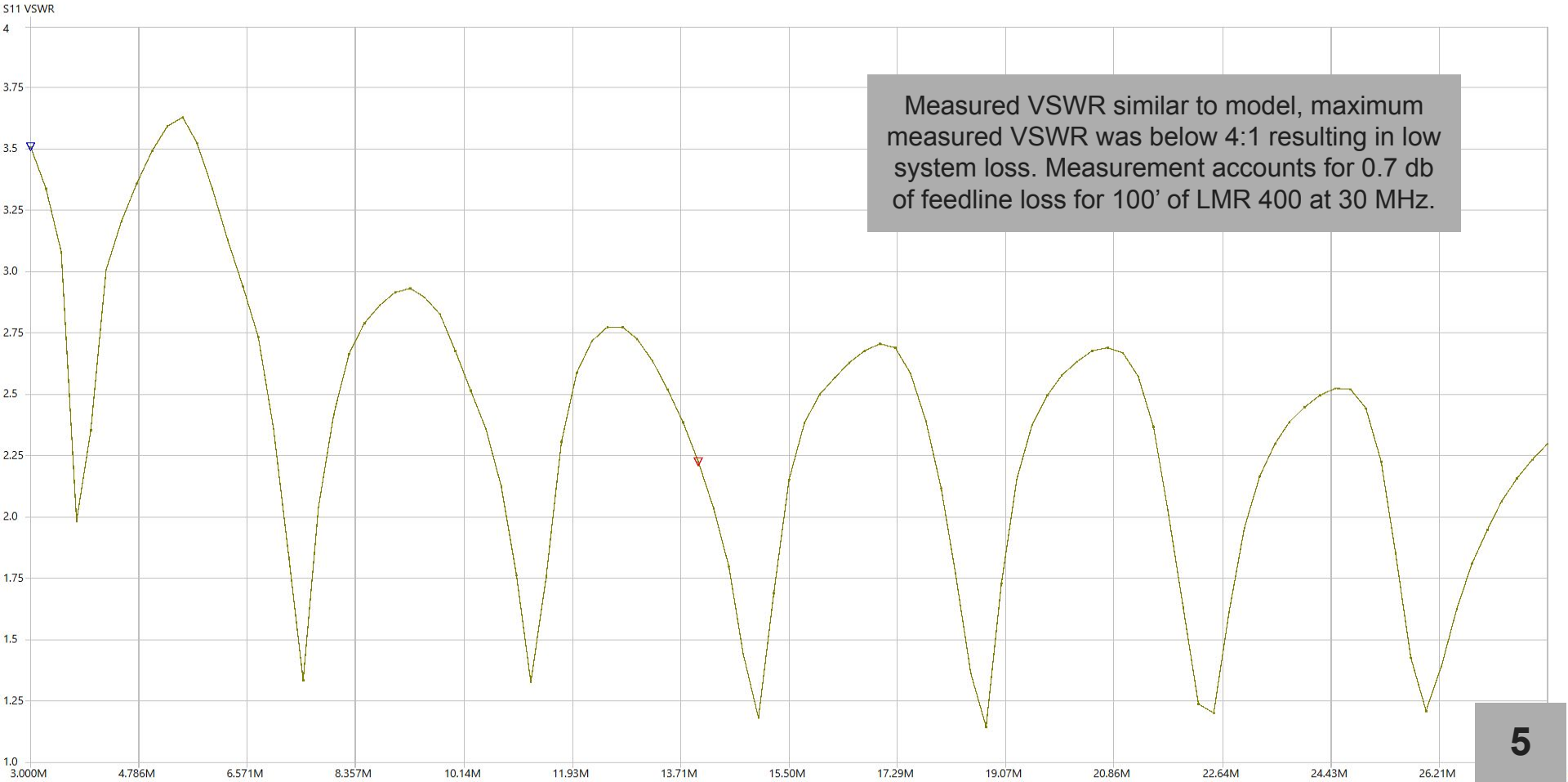


Many low VSWR points due to harmonics, design freq = 3.4MHz. VSWR expected to be below 10:1 at all points from 3.4-30MHz.

Freq	6.95 MHz
SWR	1.065
Z	47.22 at -1.45 d
	= 47.21 - j 1.198
Refl Coeff	0.03125 at -156
	= -0.02857 - j 0.
Ret Loss	30.1 dB

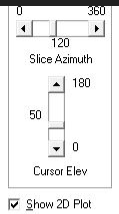
Z0

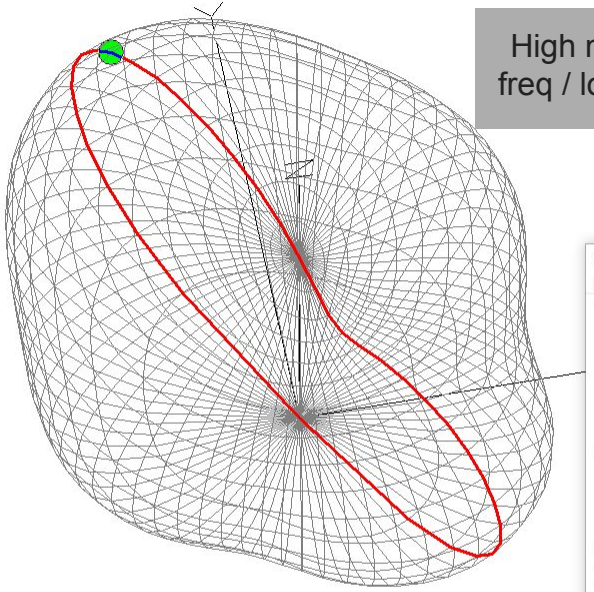
286’ Loop VSWR (Measured)



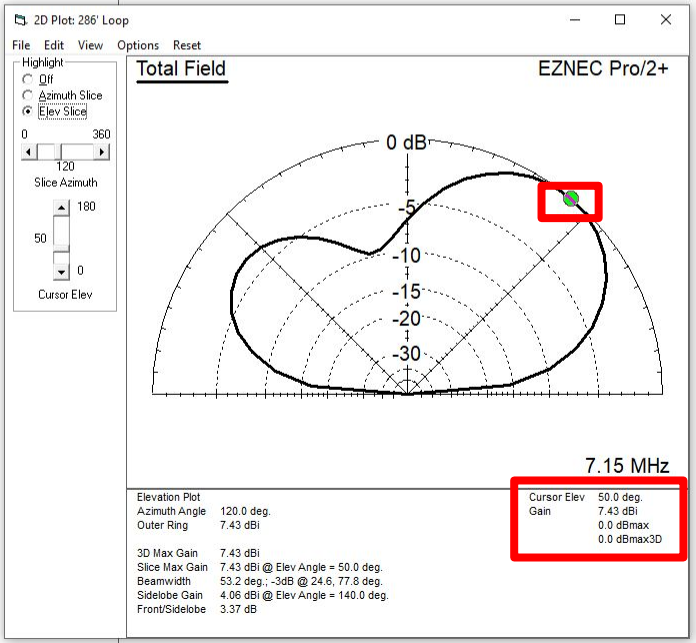
Measured VSWR similar to model, maximum measured VSWR was below 4:1 resulting in low system loss. Measurement accounts for 0.7 db of feedline loss for 100’ of LMR 400 at 30 MHz.

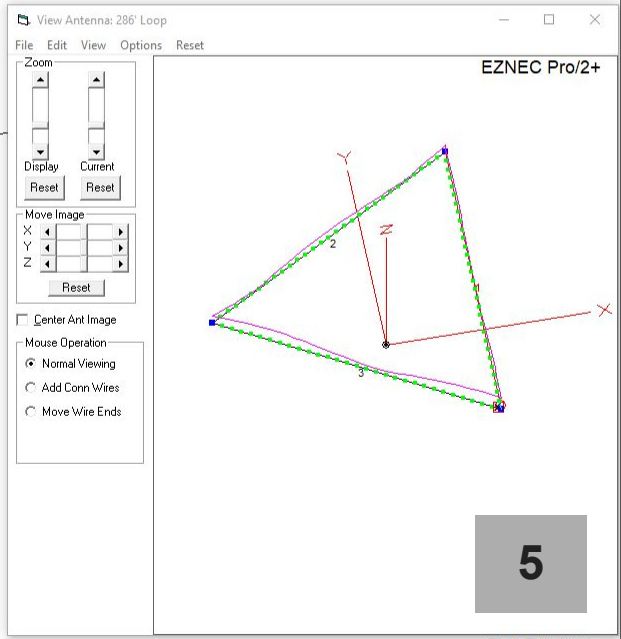
7.15 MHz Elevation Gain - 286’ Loop (Model)





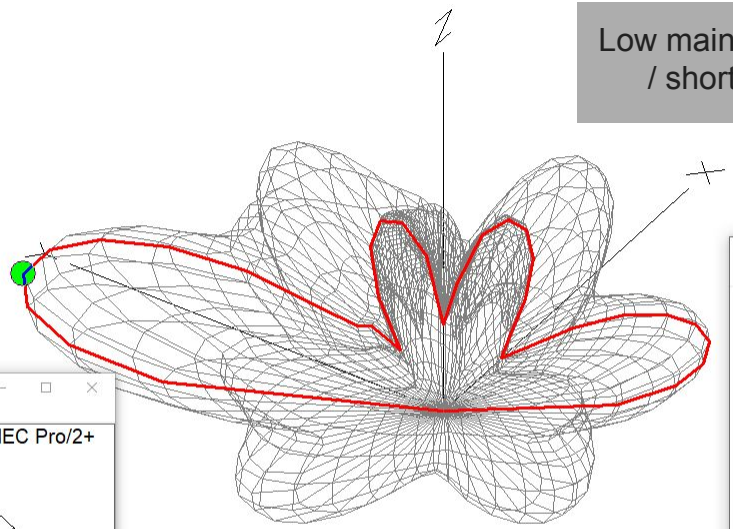
High main angle of radiation (50°) due to low freq / long wavelength and distance to ground.

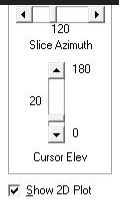


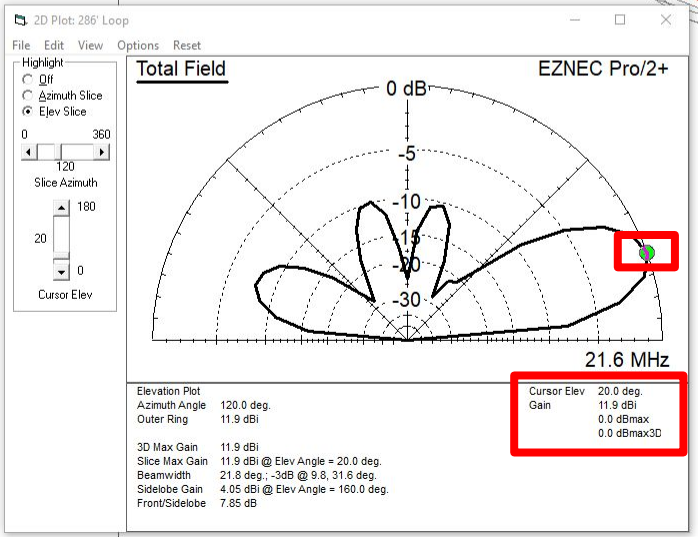


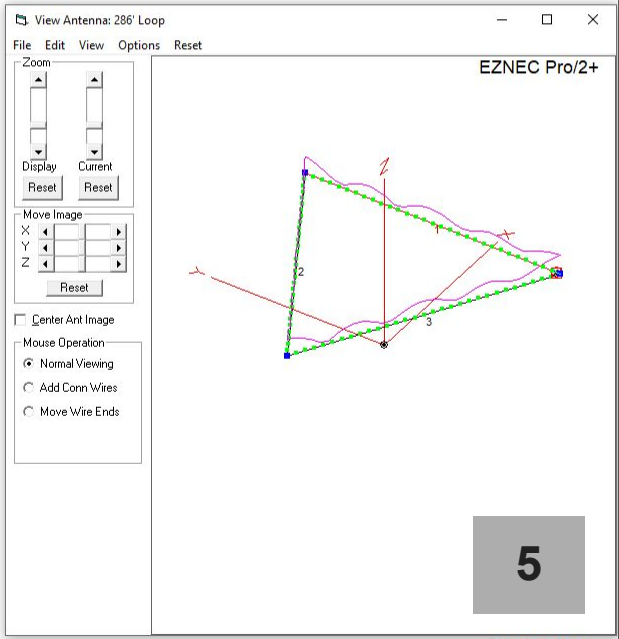
21.6 MHz Elevation Gain - 286’ Loop (Model)

Low main angle of radiation (20°) due to high freq / short wavelength and distance to ground.



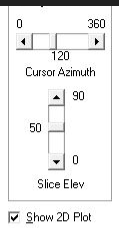


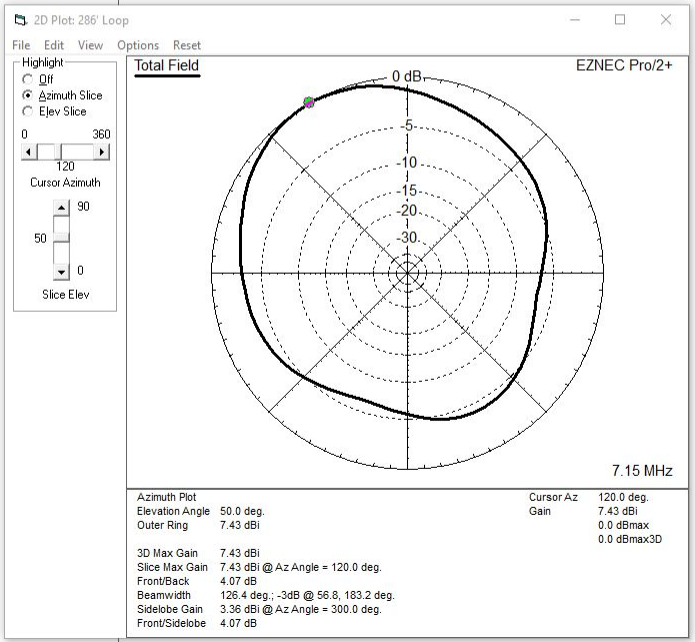


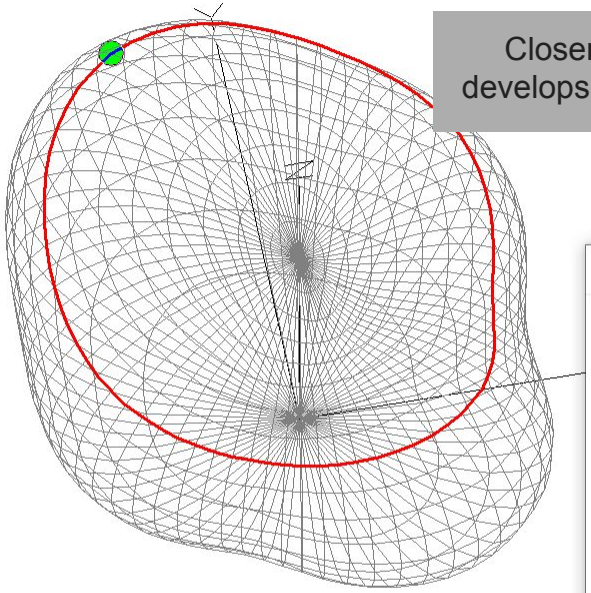


21.6 MHz

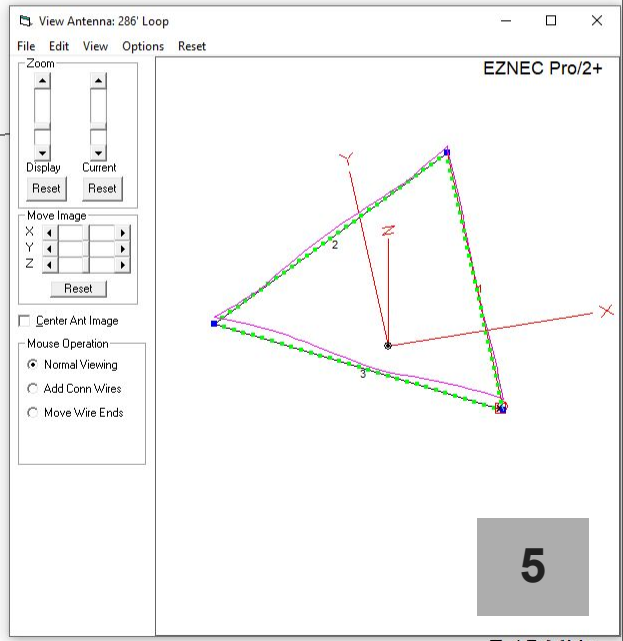
7.15 MHz Azimuth Gain - 286’ Loop (Model)







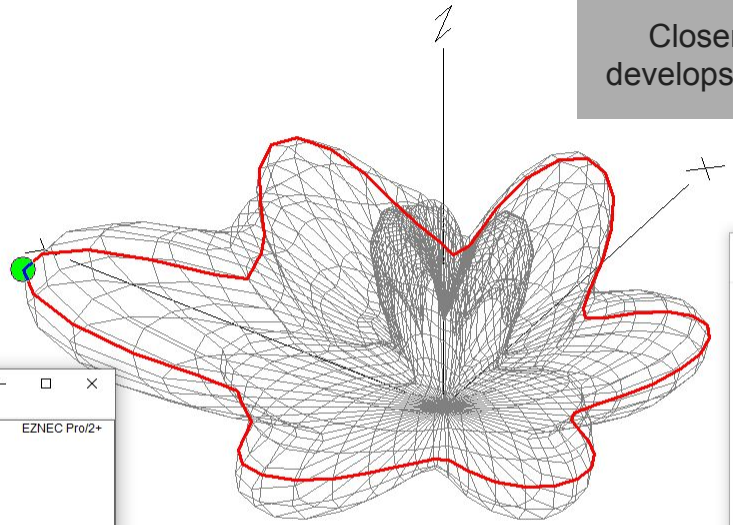
Closer to omnidirectional near design freq, develops significant nulls away from design freq.

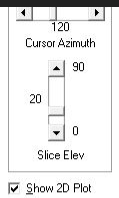


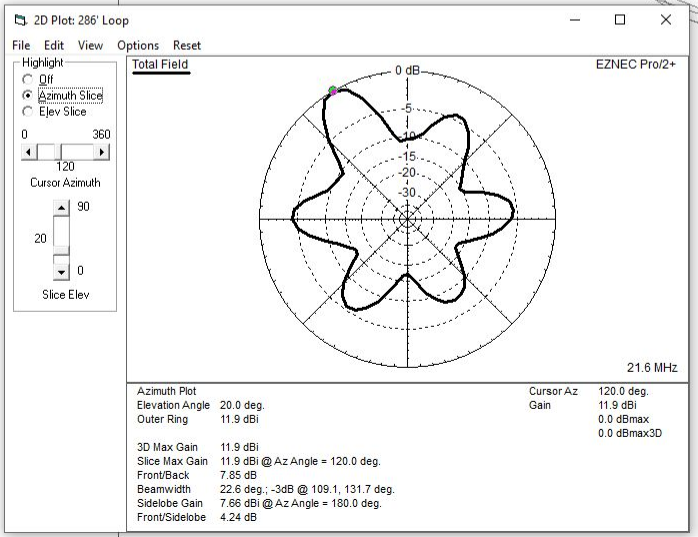
7.15 MHz

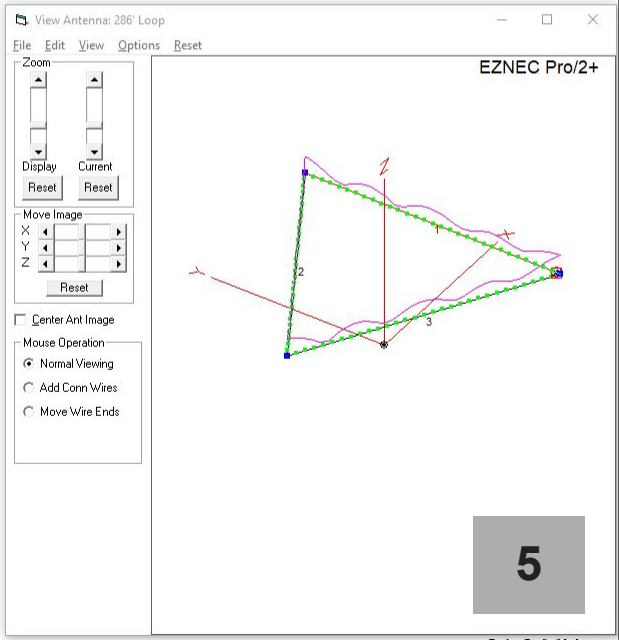
21.6 MHz Azimuth Gain - 286’ Loop (Model)

Closer to omnidirectional near design freq, develops significant nulls away from design freq.

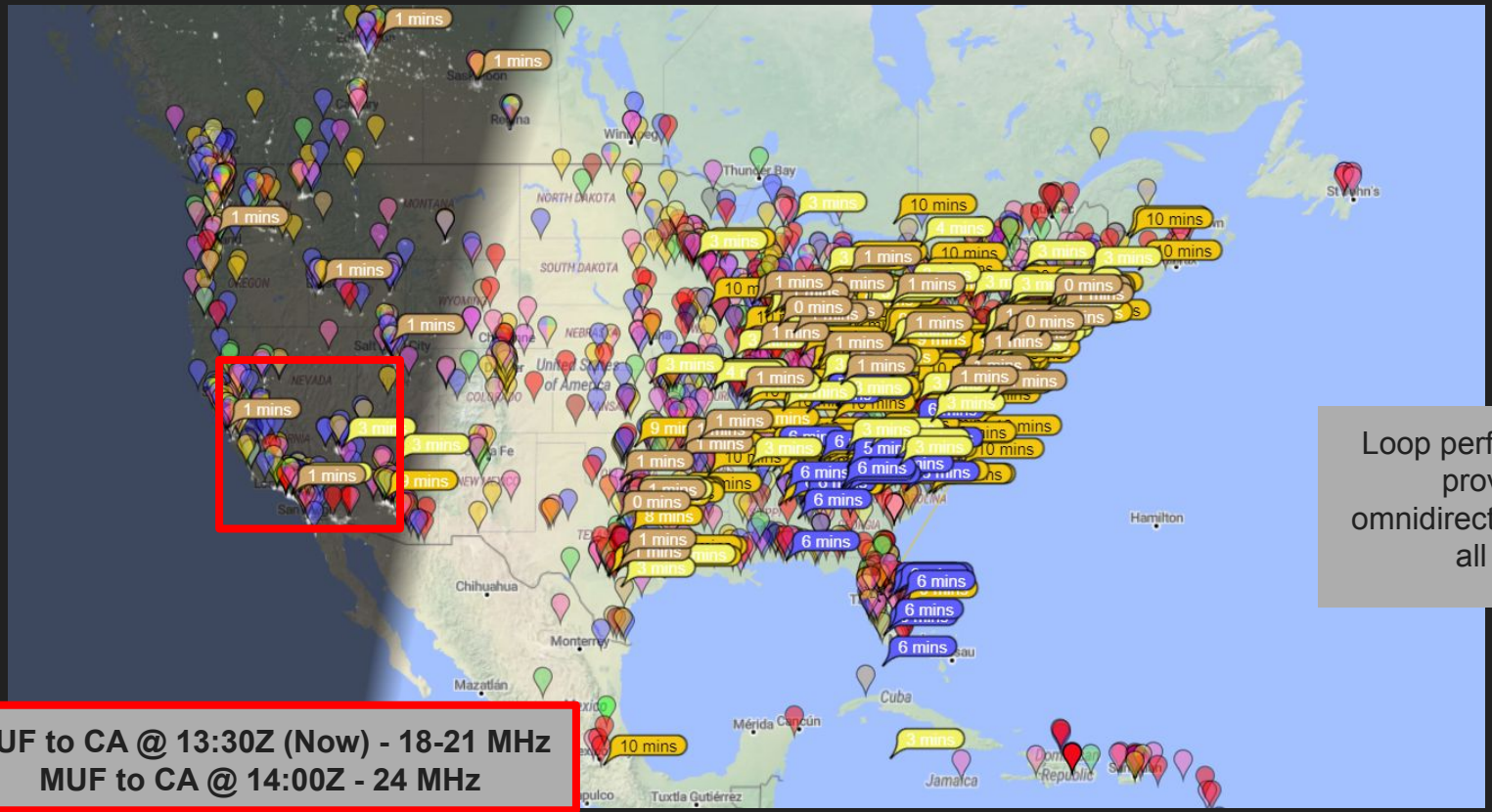








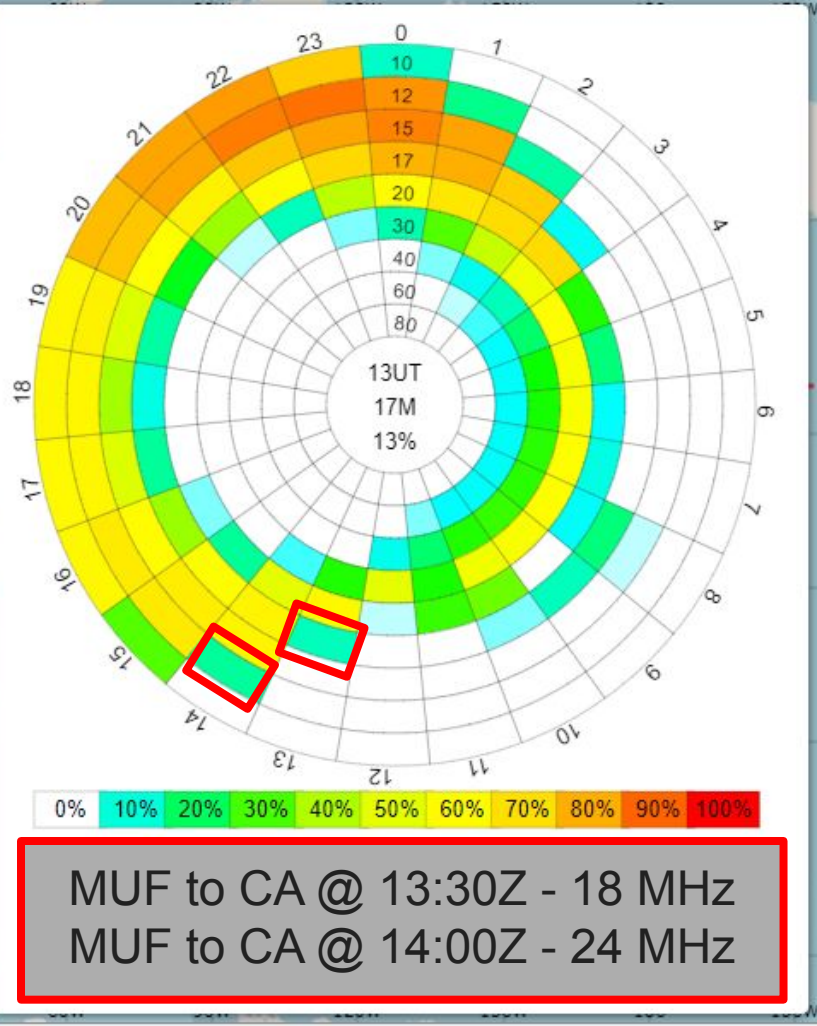
286’ Loop at 30’ // Multiband Results // 0930L (Measured)



6 mins — 7 MHz
10 mins — 14 MHz
3 mins — 18 MHz
1 mins — 21 MHz

Loop performed as expected providing roughly omnidirectional propagation at all frequencies.

MUF to CA @ 13:30Z (Now) - 18-21 MHz
MUF to CA @ 14:00Z - 24 MHz



MUF to CA @ 13:30Z - 18 MHz
MUF to CA @ 14:00Z - 24 MHz

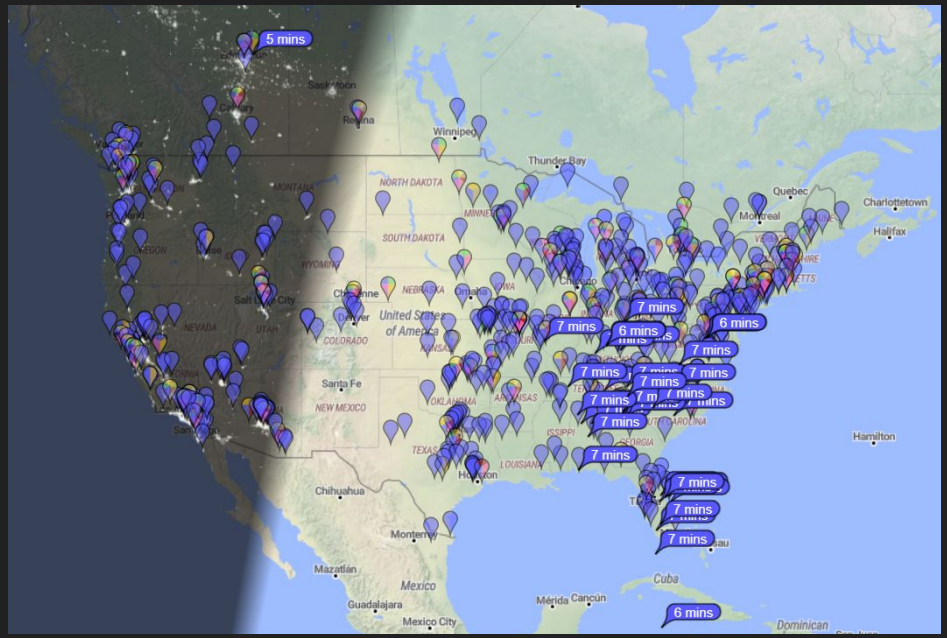
VOACAP Propagation Prediction (Model)

VOACAP Propagation prediction shows MUF to CA from Tampa should be 18 MHz at 1300Z which is slightly lower than the measured MUF.

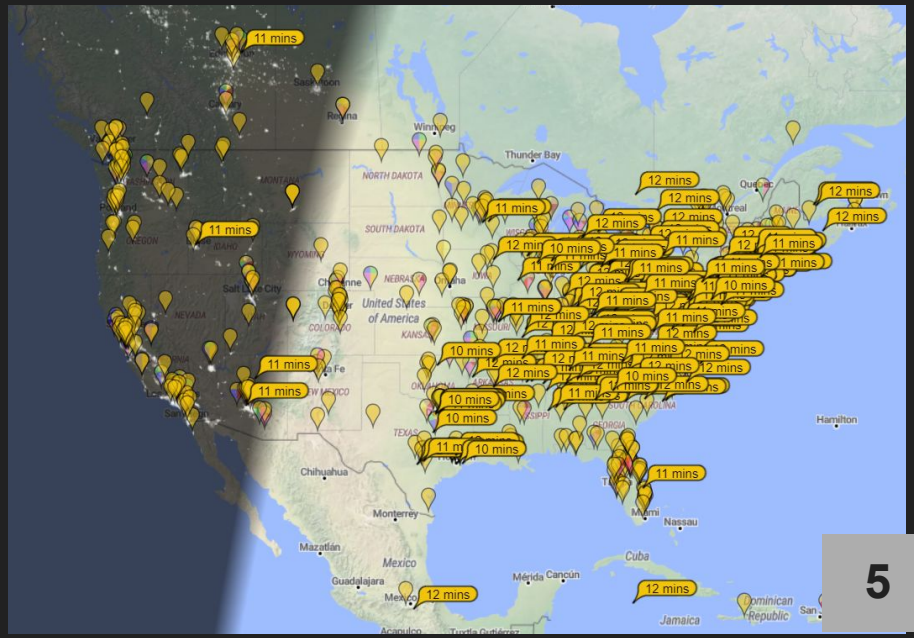
TX: 28.30, -82.27 | RX: 38.82, -122.01 | Short: 3837 km — 2384 mi | 298° — 96° | Mid: 35.2061, -100.8819 | Long: 36171 km — 22476 mi | 118° — 276° | Mid: -35.2061, 79.1181

286’ Loop at 30’ // Frequency Comparison // 0930L

7 MHz

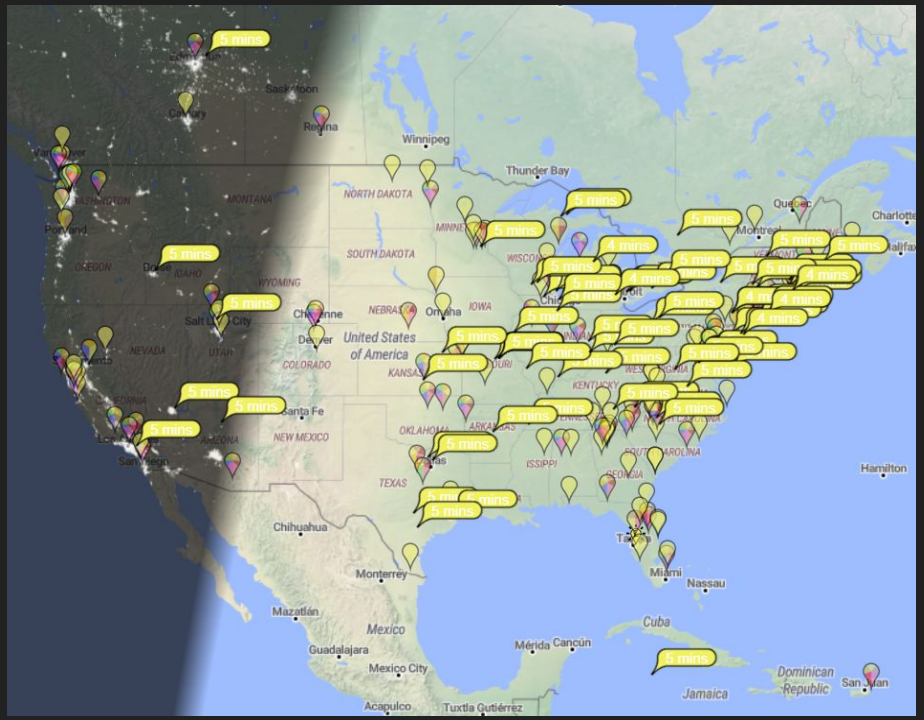


14 MHz

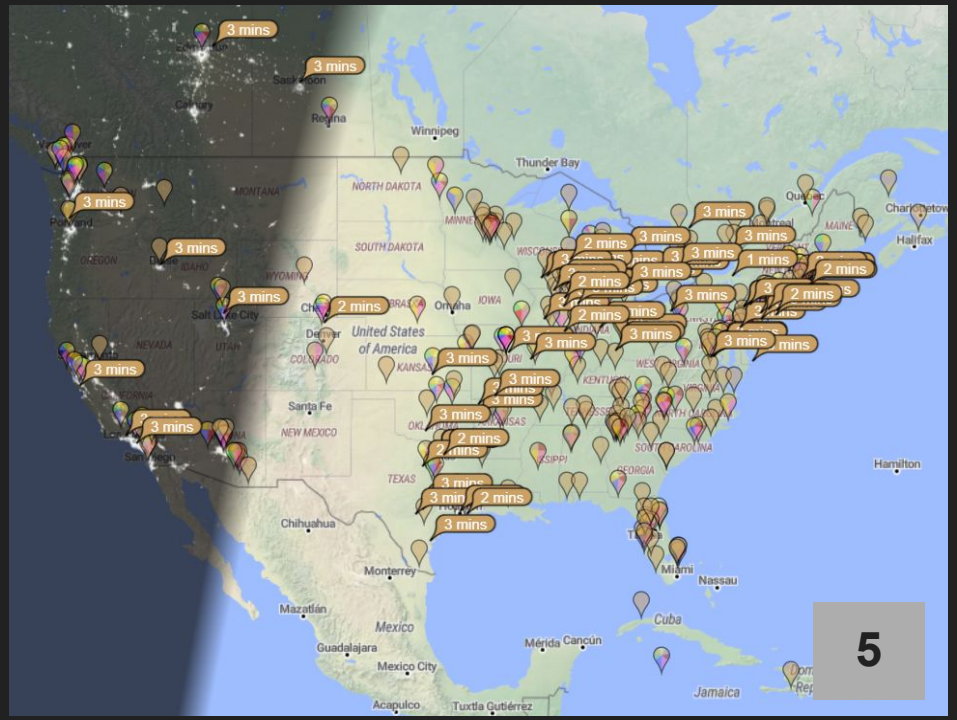


286’ Loop at 30’ // Frequency Comparison // 0935L

18 MHz

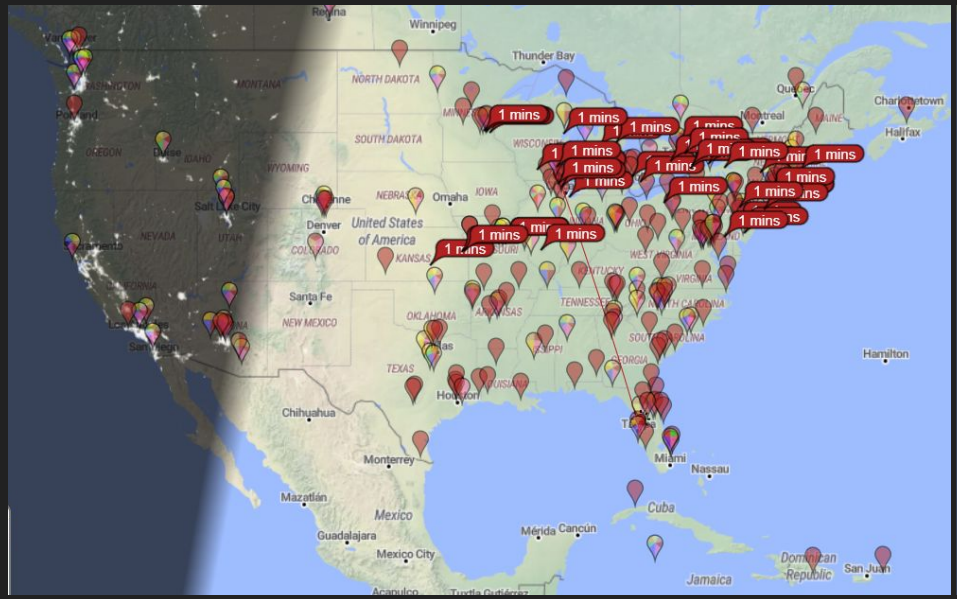


21 MHz

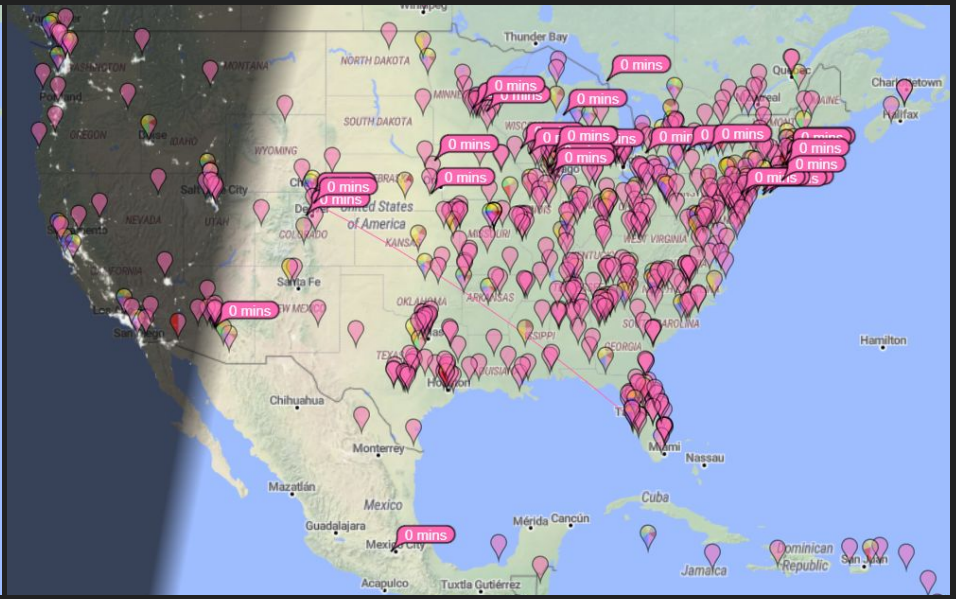


286’ Loop at 30’ // Frequency Comparison // 0935L

24 MHz

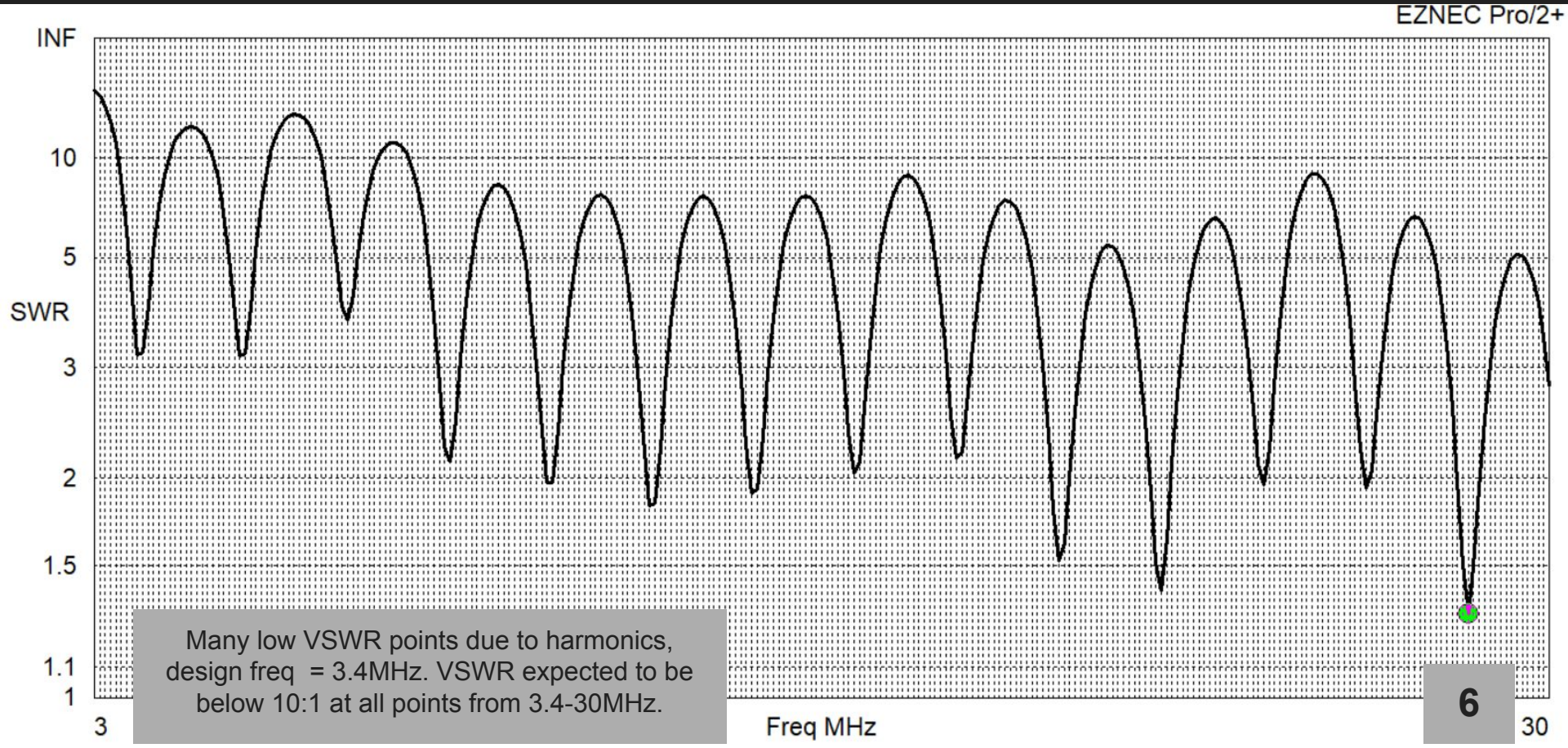


28 MHz



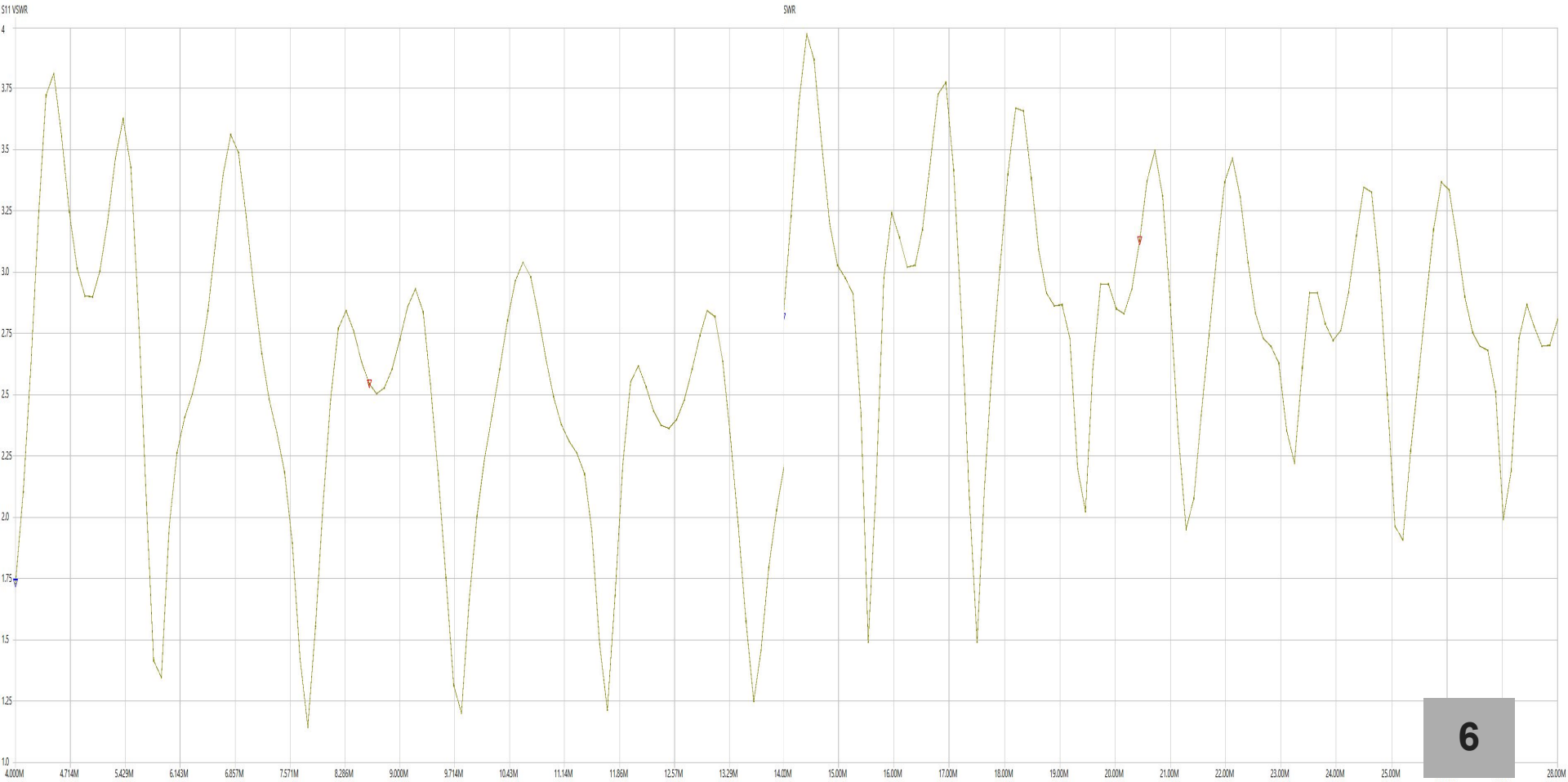
500’ Delta Loop

500’ Loop VSWR (Model)



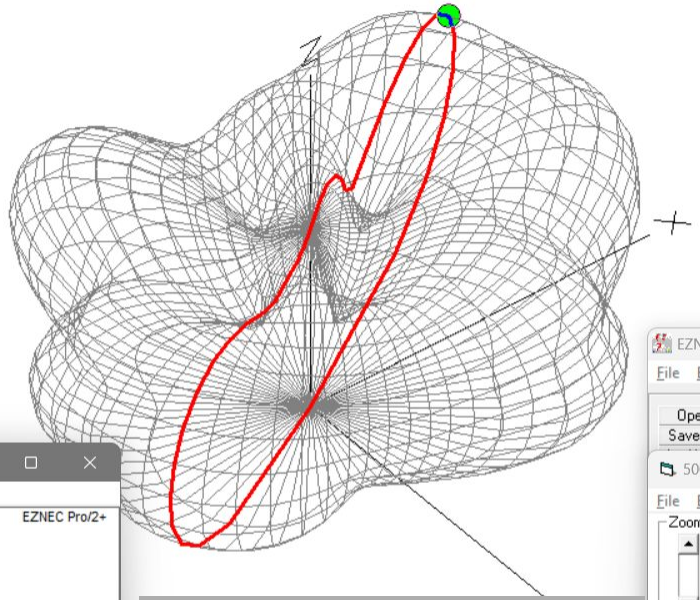
Many low VSWR points due to harmonics, design freq = 3.4MHz. VSWR expected to be below 10:1 at all points from 3.4-30MHz.

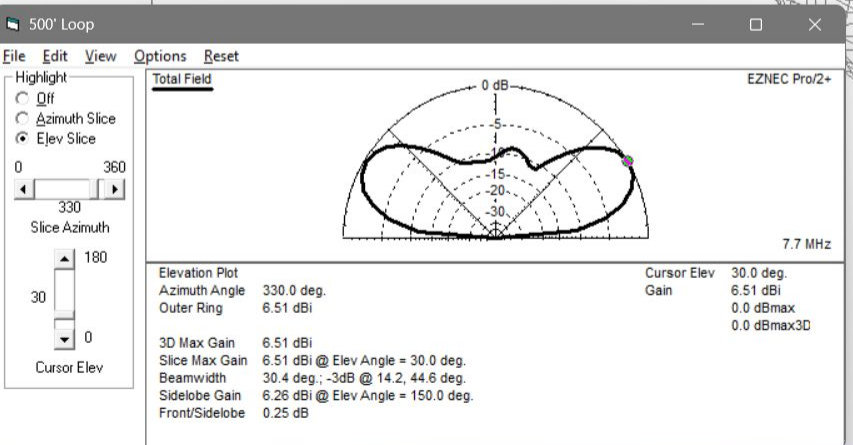
500’ Loop VSWR (Measured)



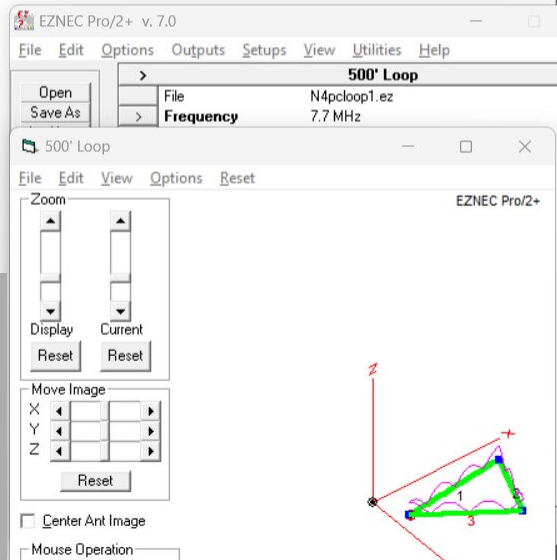
500’ Delta Loop Elevation Gain - 7.7 MHz (Model)

Provides short and medium haul night time comms and short distance daytime comms.



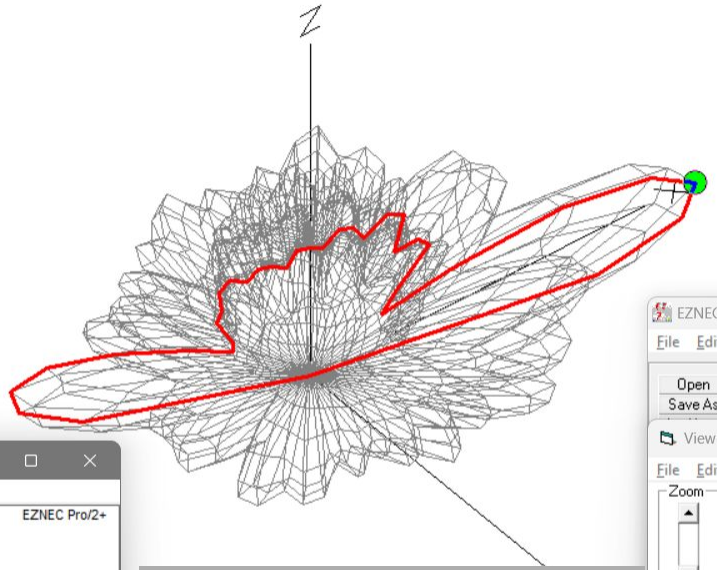


Non-uniform shape caused by irregular triangle layout. 6.51 dBi of gain @ 30 deg.

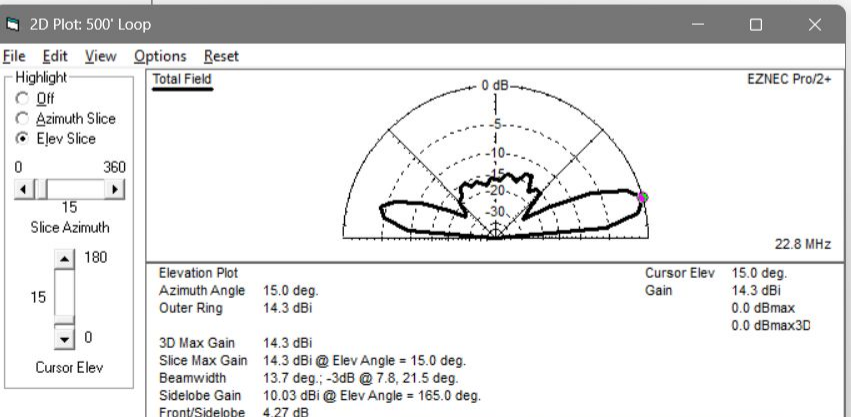


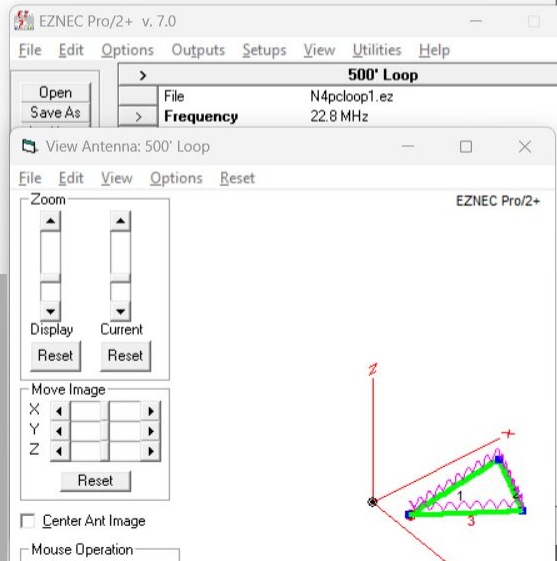
500’ Delta Loop Elevation Gain - 22.8 MHz (Model)

Provides highly directional long haul daytime comms and omnidirectional short haul comms.

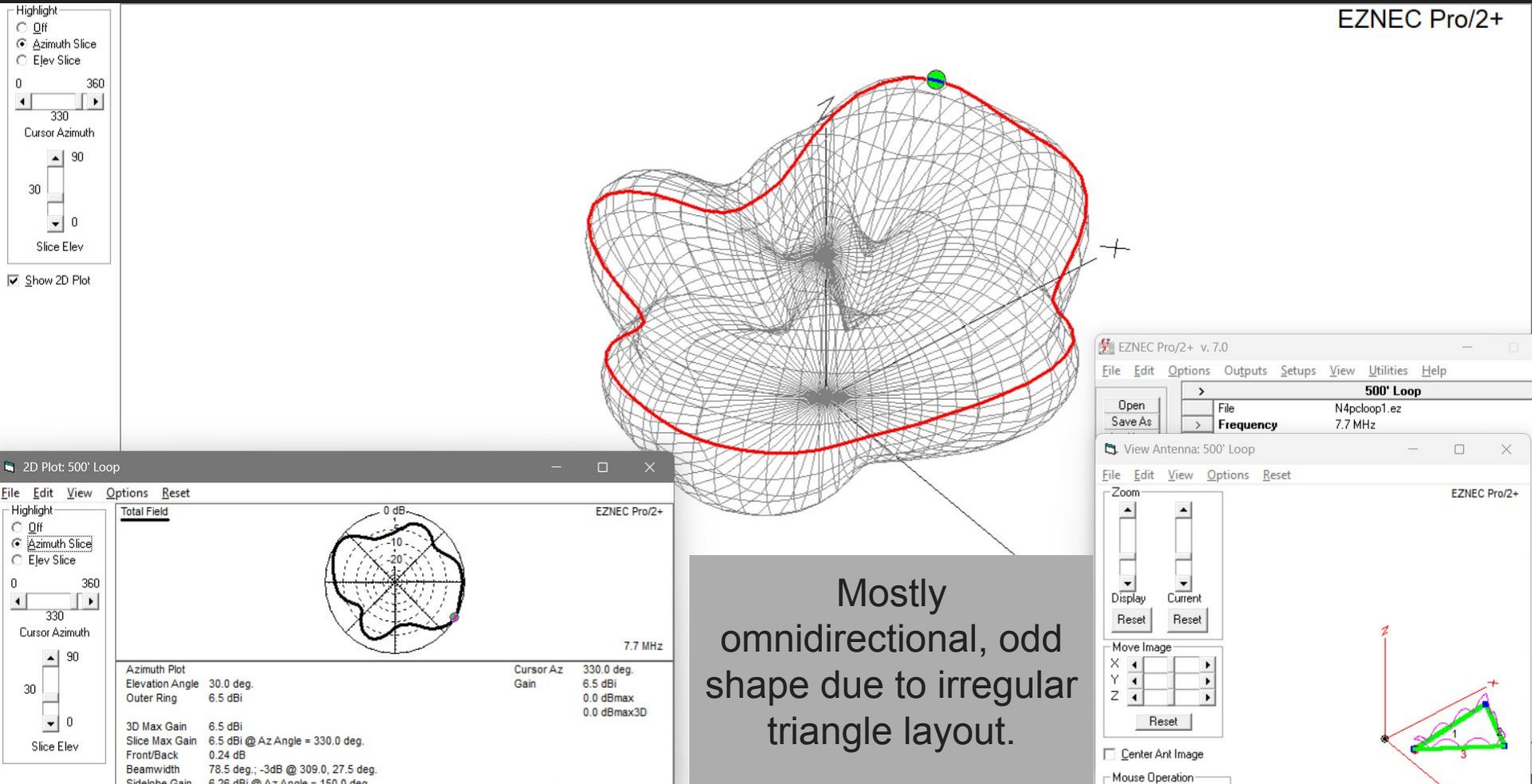


Main lobe at 15 degrees elevation with 14.3 dBi of gain.





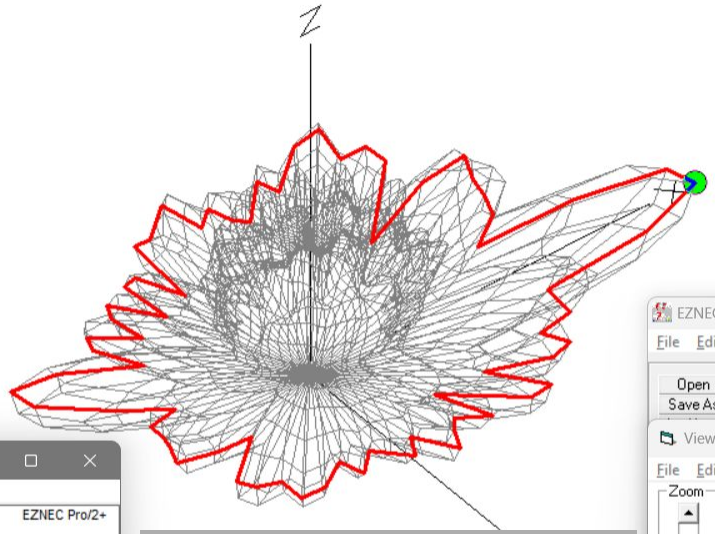
500’ Delta Loop Azimuth Gain - 7.7 MHz (Model)



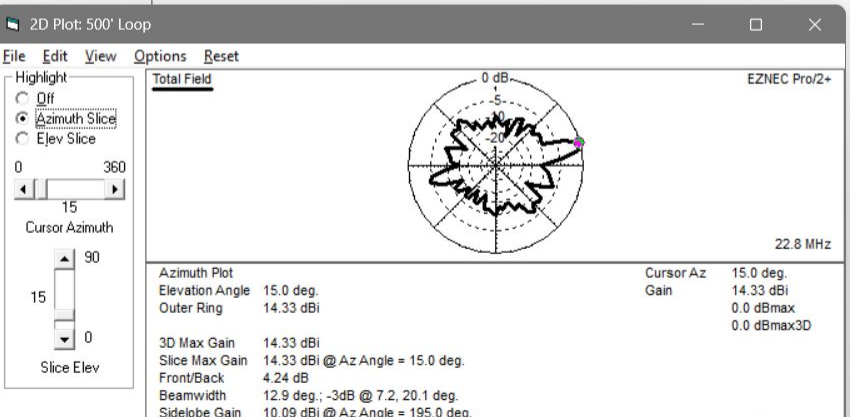
Mostly omnidirectional, odd shape due to irregular triangle layout.

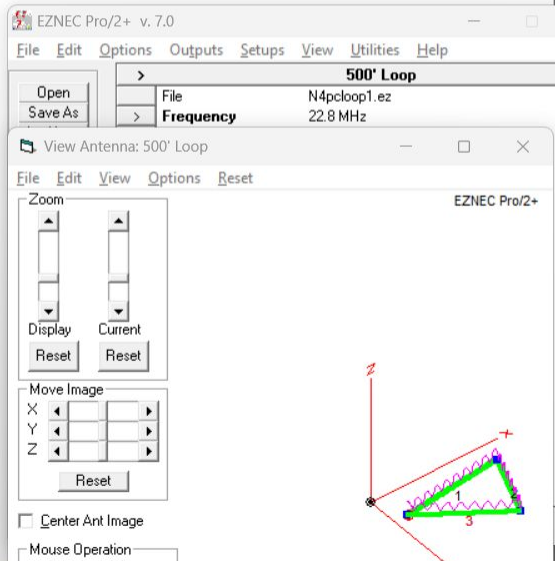
500’ Delta Loop Azimuth Gain - 22.8 MHz (Model)

Provides highly directional long haul daytime comms and omnidirectional short haul comms.



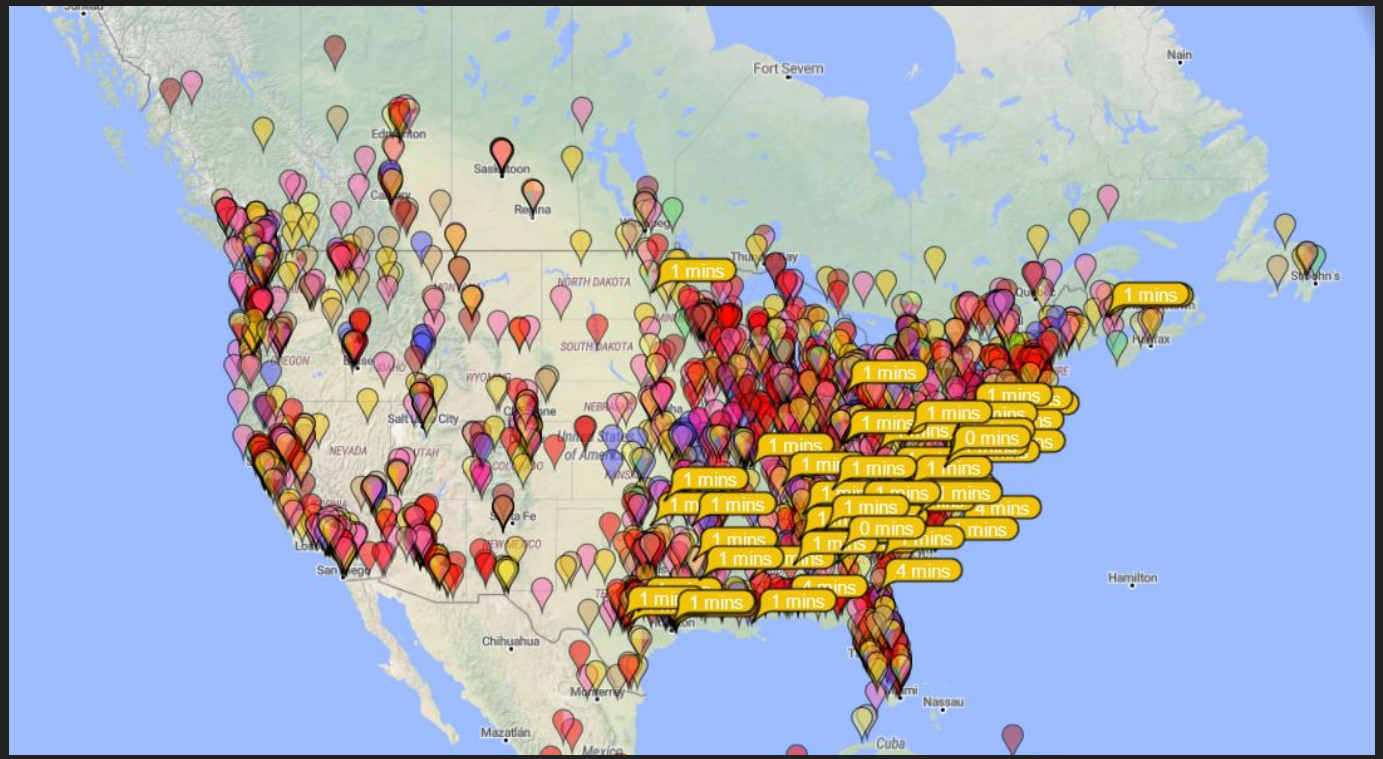
Main lobe has significant gain over a very narrow beamwidth with 0-5 dBi of gain omnidirectionally.





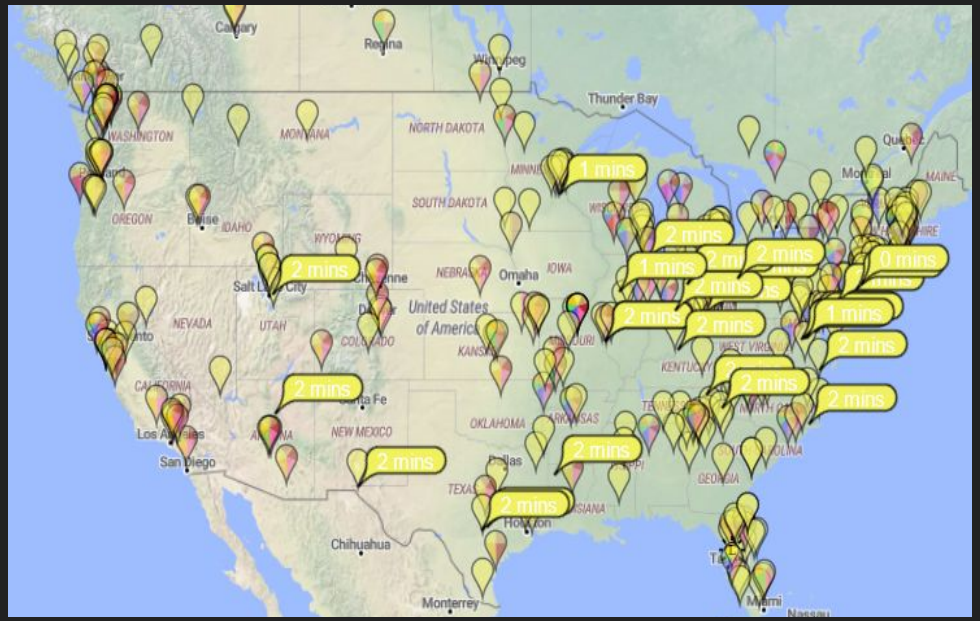
500’ Loop at 30’ // Frequency Comparison // 1545L

14 MHz



500’ Loop at 30’ // Frequency Comparison // 1550L

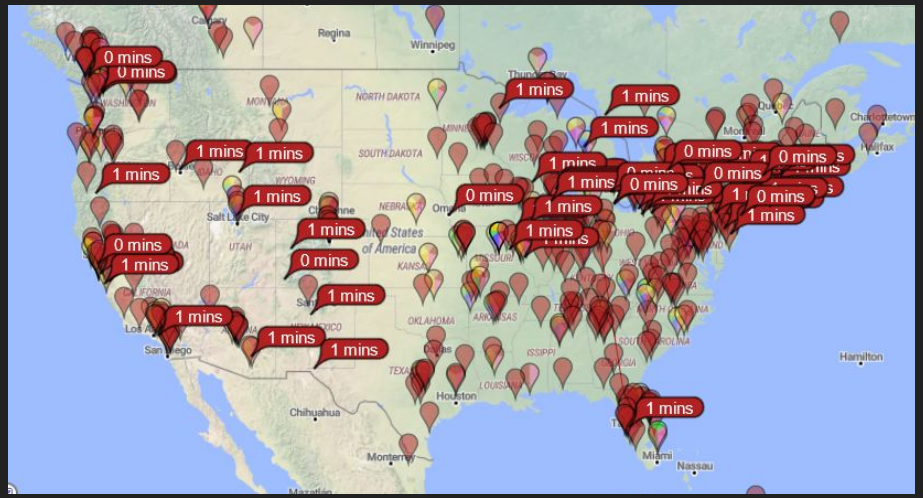
18 MHz



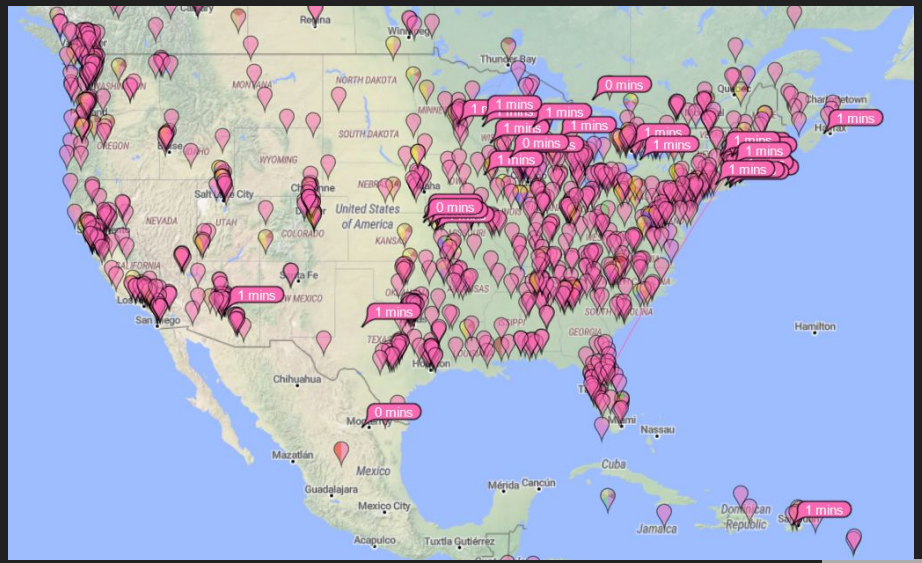
21 MHz

500’ Loop at 30’ // Frequency Comparison // 1555L

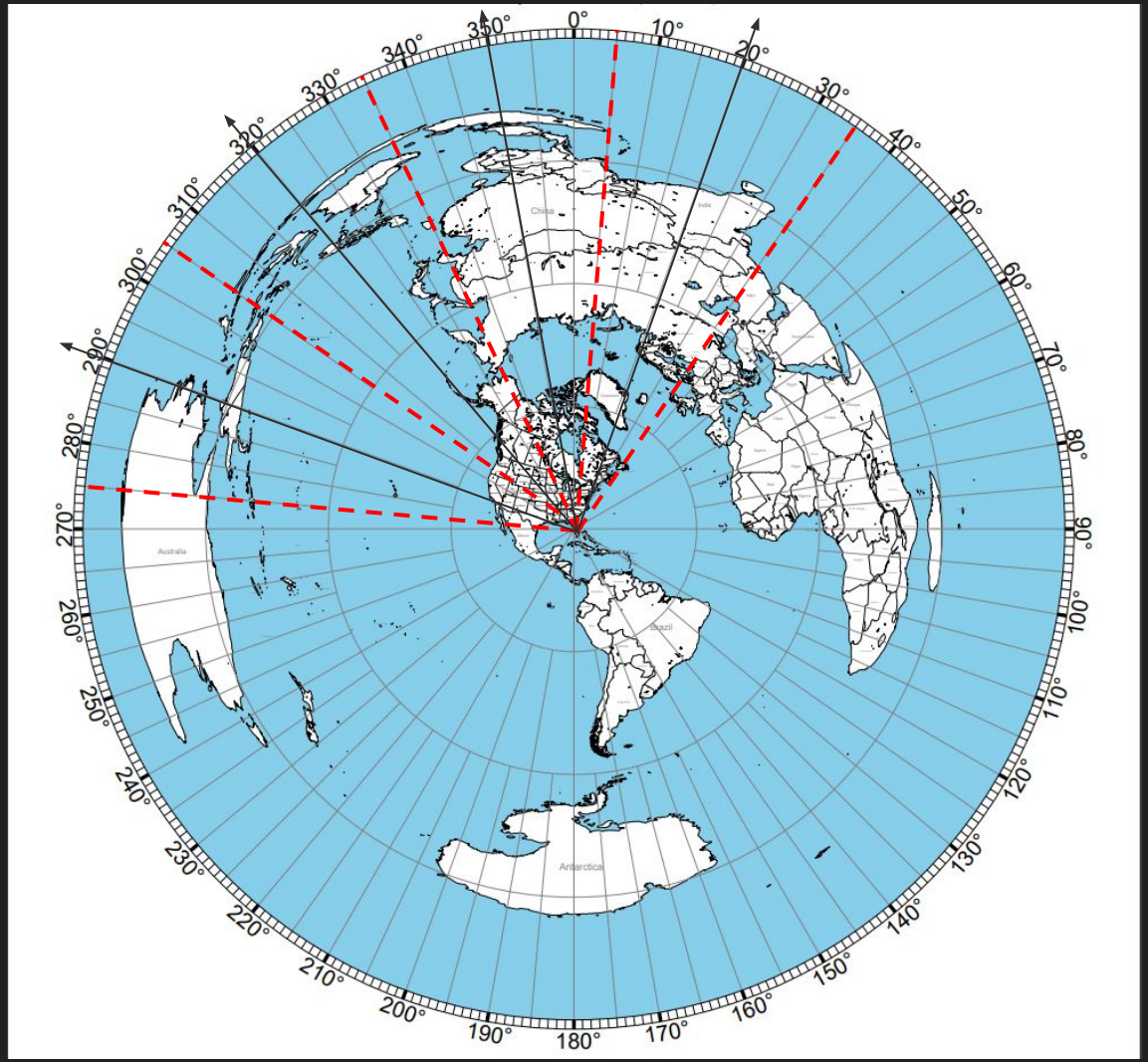
24 MHz



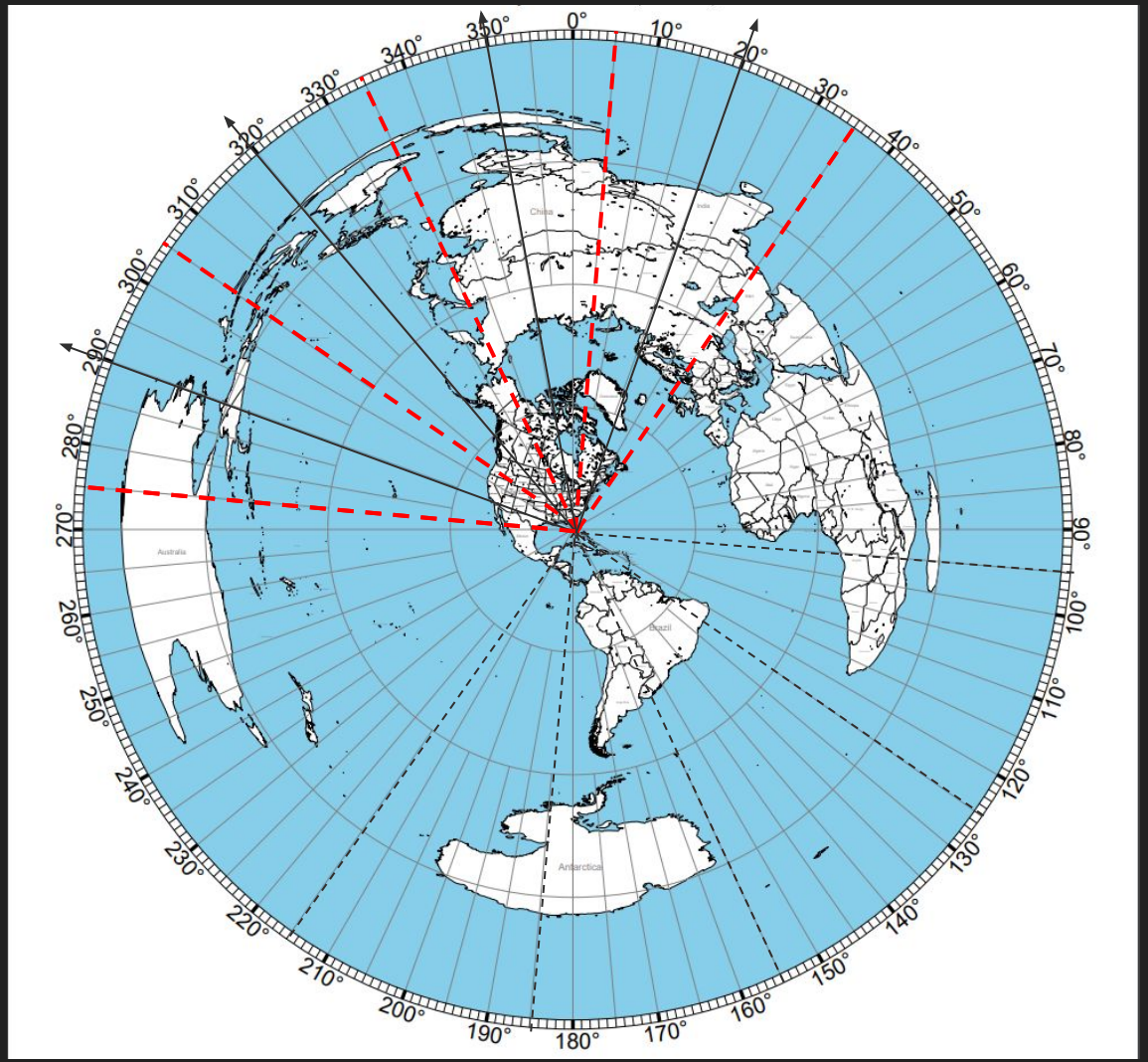
28 MHz

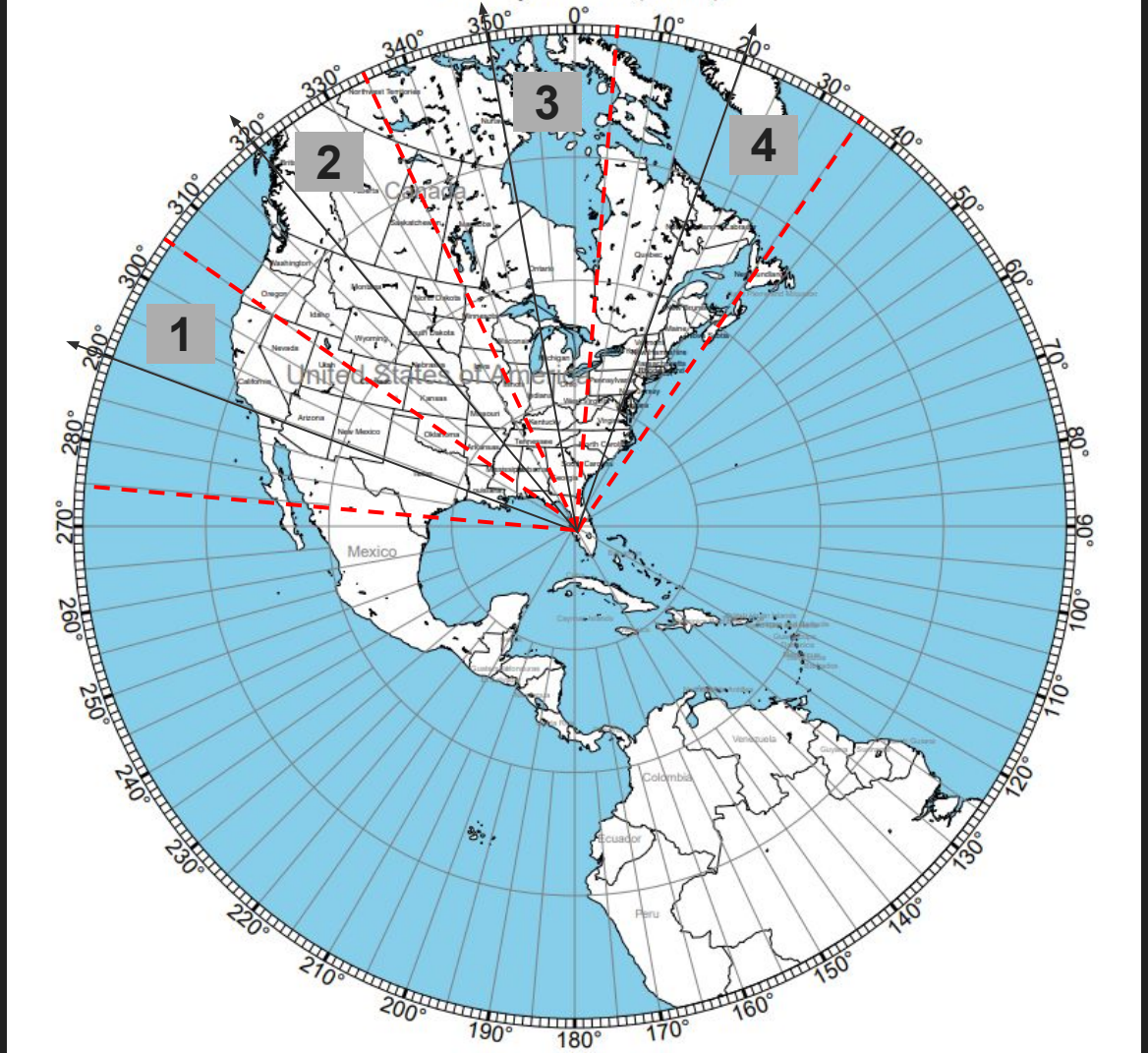


Longwires


0°
10°
20°
30°
40°
50°
60°
70°
80°
90°
100°
110°
120°
130°
140°
150°
160°
170°
180°
190°
200°
210°
220°
230°
240°
250°
260°
270°
280°
290°
300°
310°
320°
330°
340°
350°
China
Australia
Brazil
Antarctica

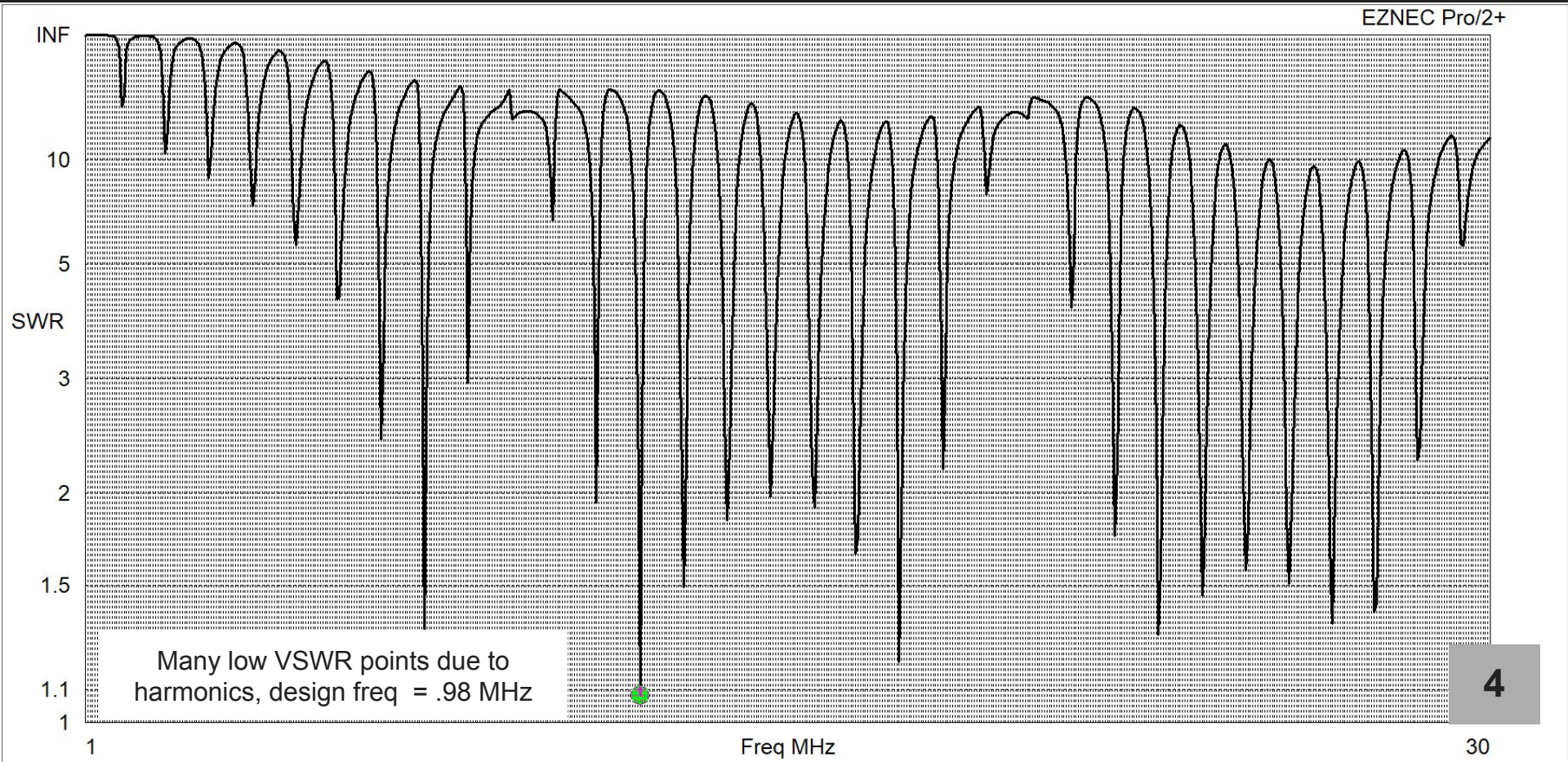
Antenna Overview


0°
10°
20°
30°
40°
50°
60°
70°
80°
90°
100°
110°
120°
130°
140°
150°
160°
170°
180°
190°
200°
210°
220°
230°
240°
250°
260°
270°
280°
290°
300°
310°
320°
330°
340°
350°
China
India
Australia
Brazil
Antarctica
Key:
Physical Antenna
Coverage Area

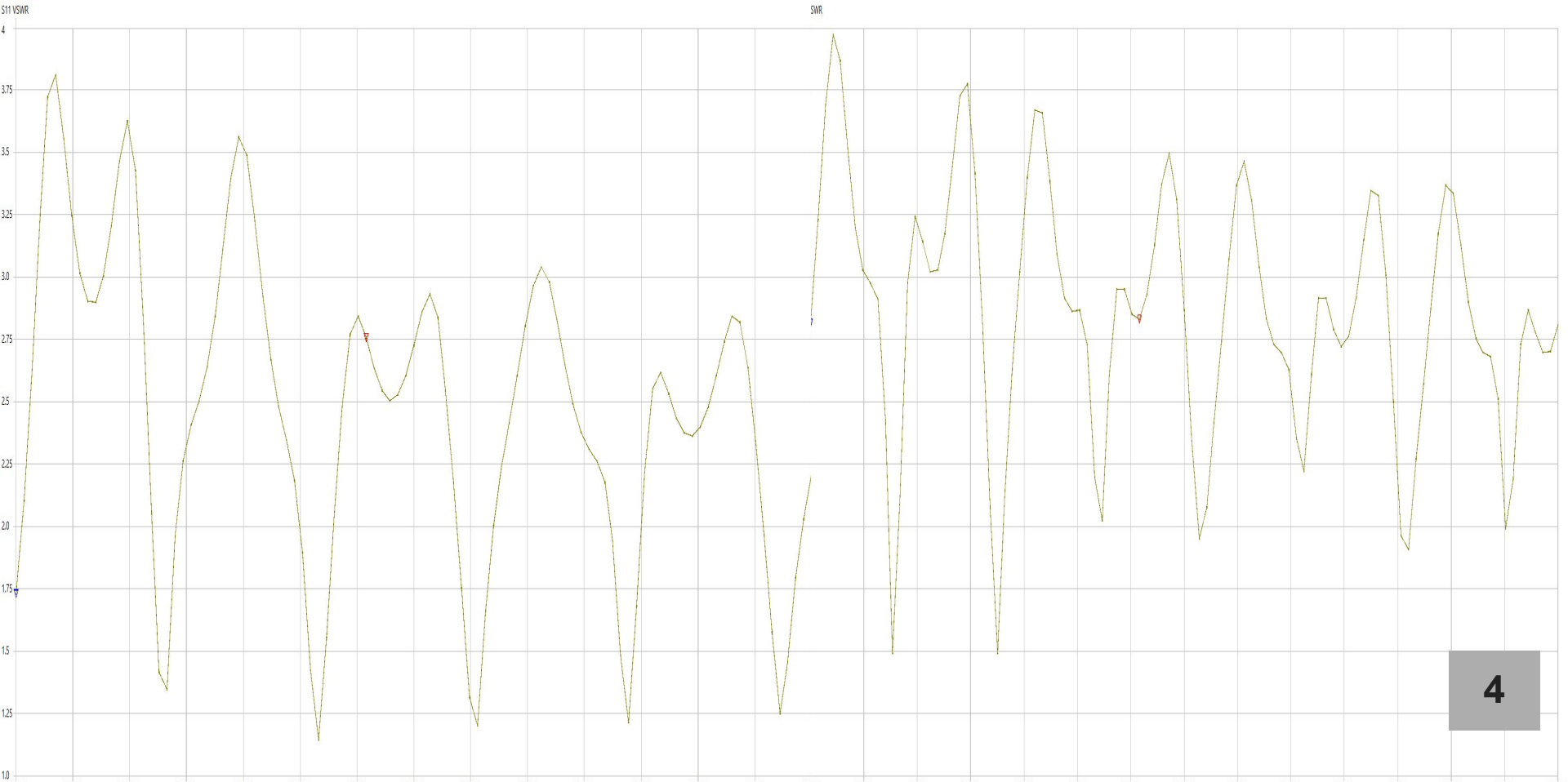

1
2
3
4
Canada
United States of America
Mexico
Colombia
Ecuador
Peru
Venezuela
Key:
Physical Antenna
Coverage Area

NE Longwire (500’, 20 AWG)

Model VSWR (500')

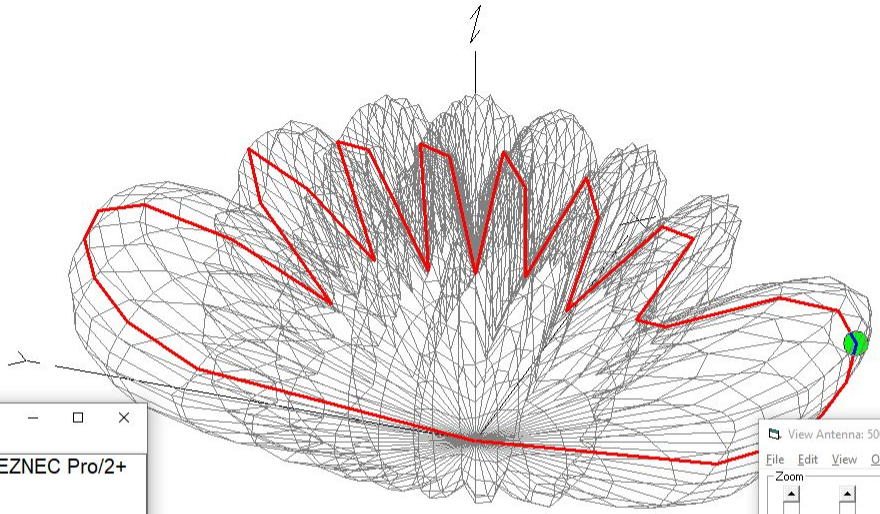


Measured VSWR (500’)

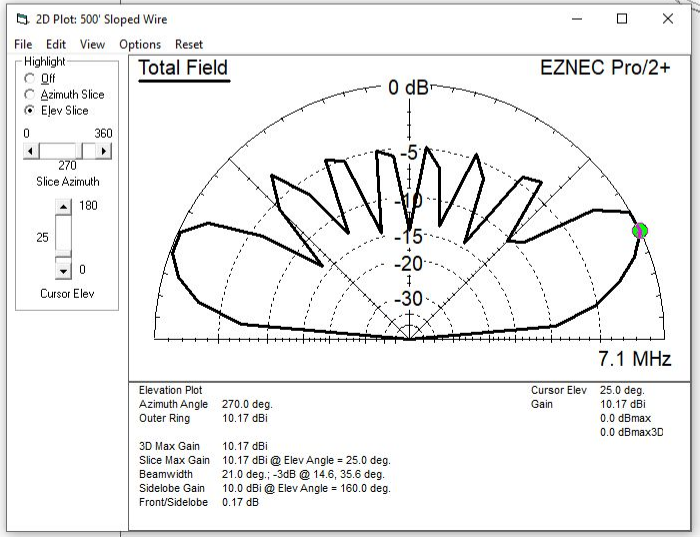


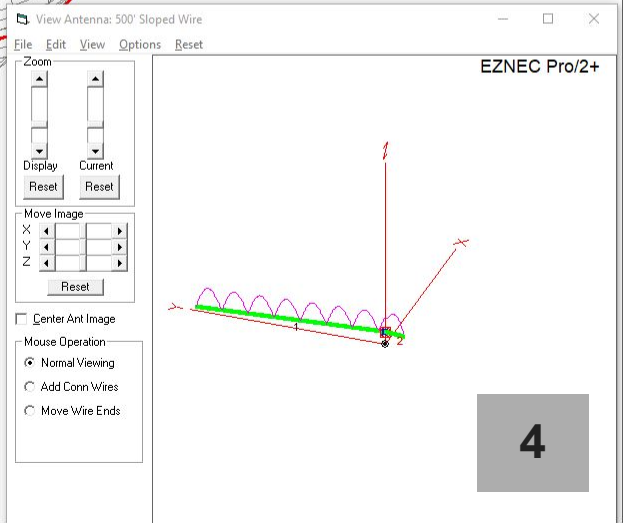
7.1 MHz Elevation Gain (Model)

Provides short, medium, and long haul night time comms and short distance daytime comms.

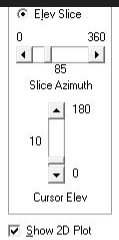


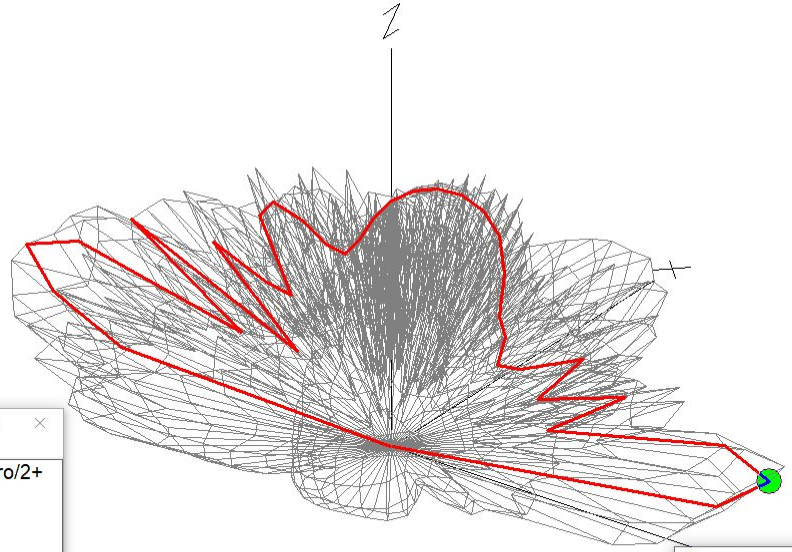
Main lobe expected to have 10.17 dBi of gain at 25 degrees elevation at 7.1 MHz. Sidelobes show up to 5 dBi of gain.

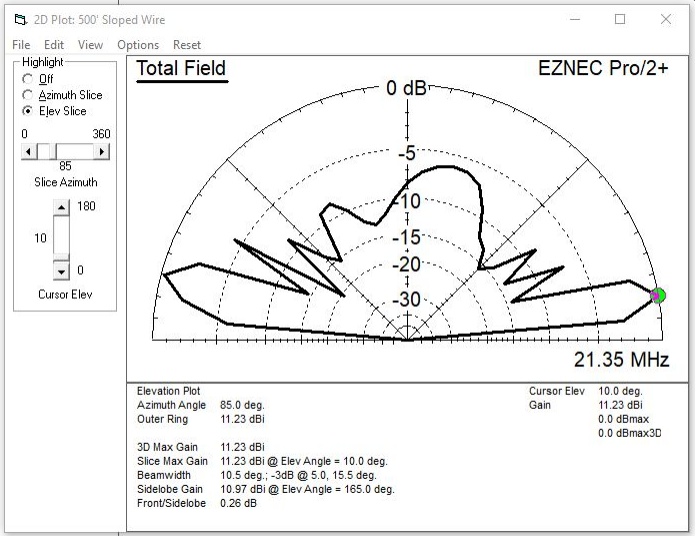




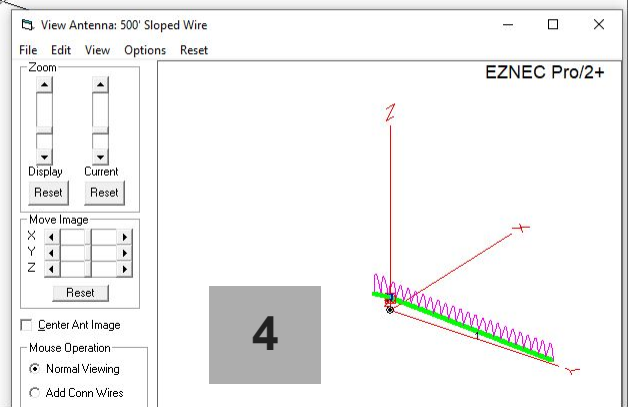
21.35 MHz Elevation Gain (Model)





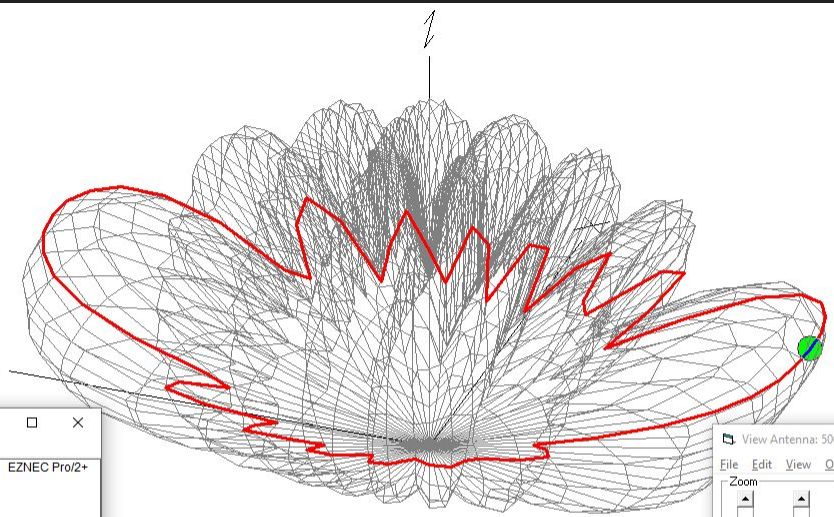


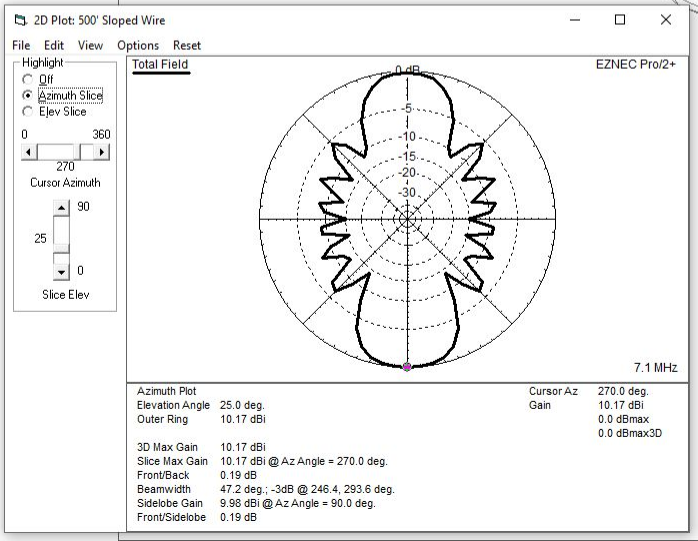
Main lobe expected to have 11.23 dBi of gain at 10 degrees elevation at 21.35 MHz. Provides long haul day time comms.



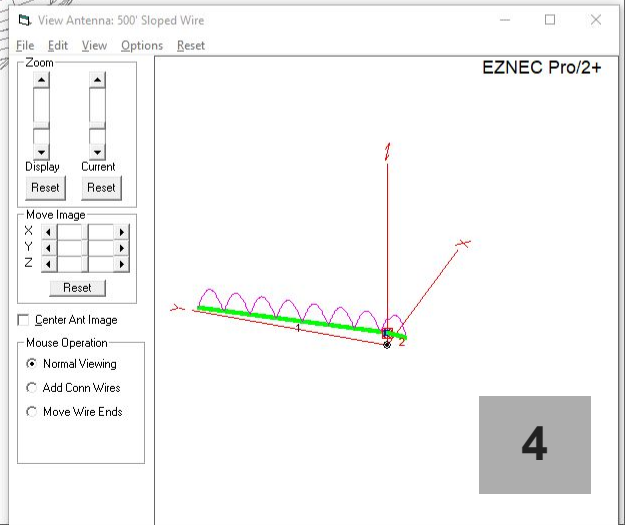
7.1 MHz Azimuth Gain (Model)

Antenna expected to provide strong bidirectional coverage with little predictability for reception on side lobes.



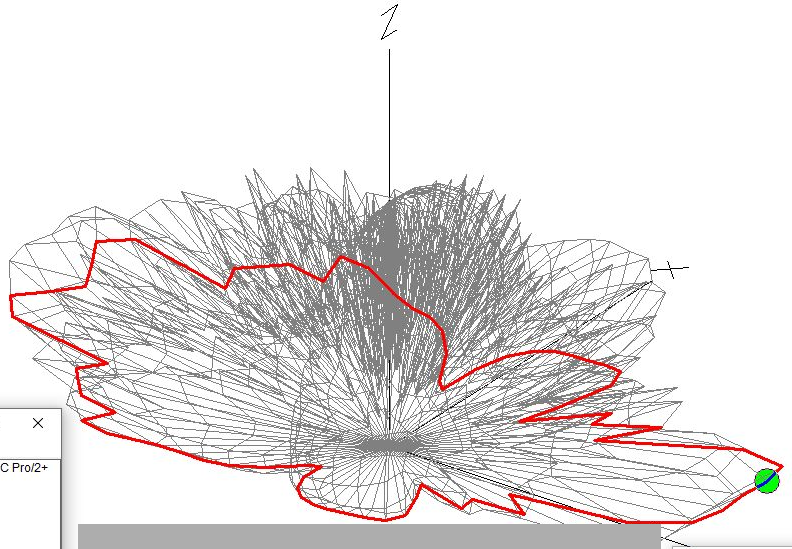


Main lobe expected to have 10.17 dBi of gain over a 45 degree beam width at 7.1 MHz. Side lobes expected to have -5 to 5 dBi of gain.

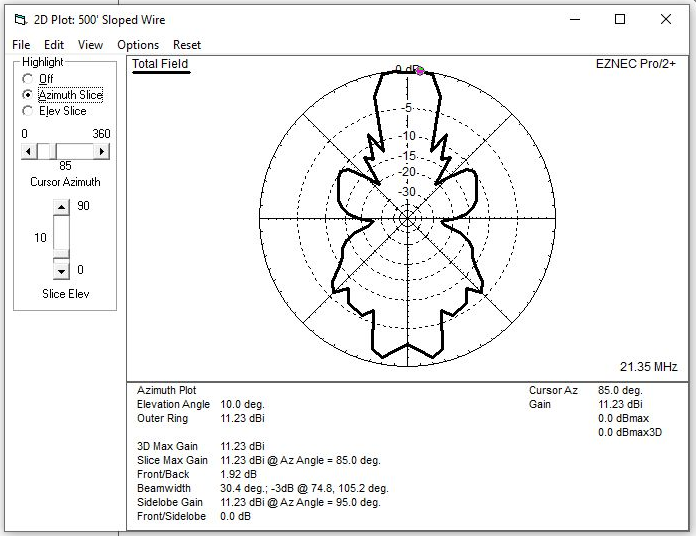


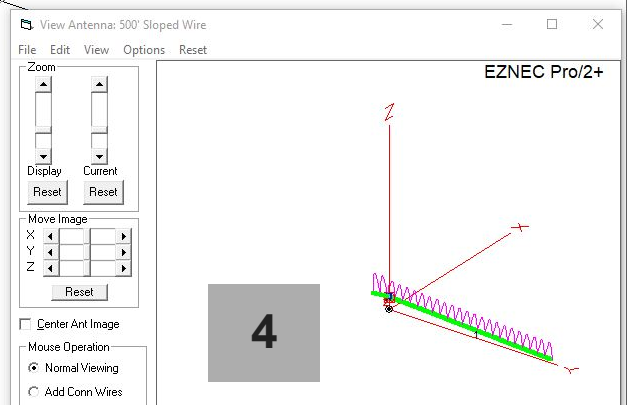
21.35 MHz Azimuth Gain (Model)

Antenna expected to provide strong bidirectional coverage with little predictability for reception on side lobes.



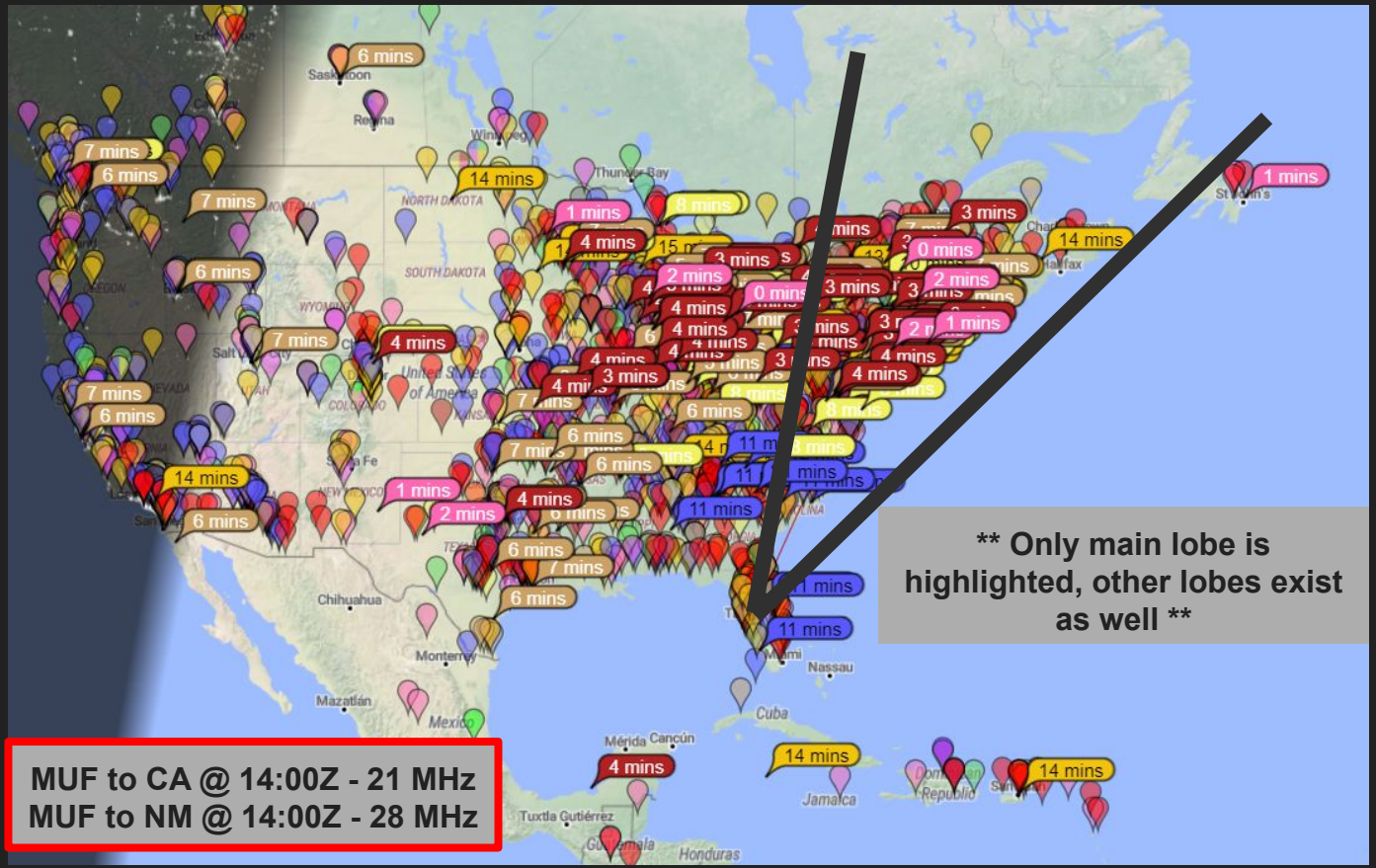
Main lobe expected to have 11.23 dBi of gain over a 30 degree beam width at 21.35 MHz. Side lobes show deep nulls with up to 5 dBi of gain.





Combined Signal Reports (Measured)

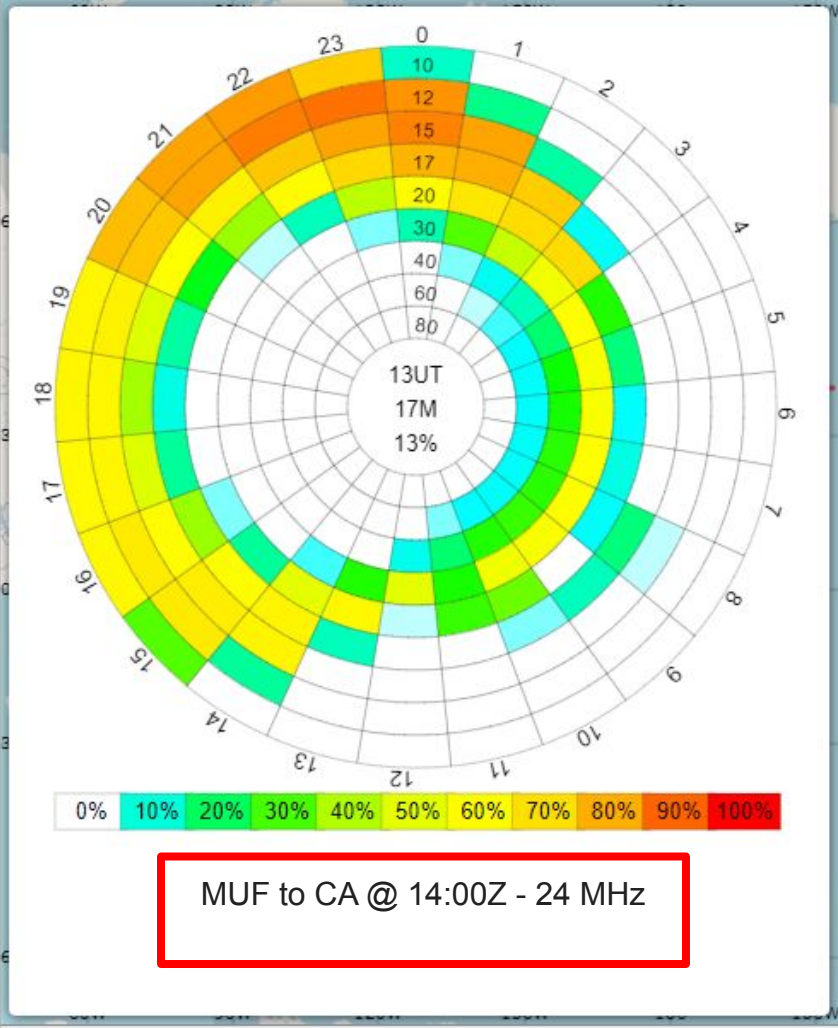
500’ Sloped Wire // 35’ // 20° // Multiband Results // 1000L



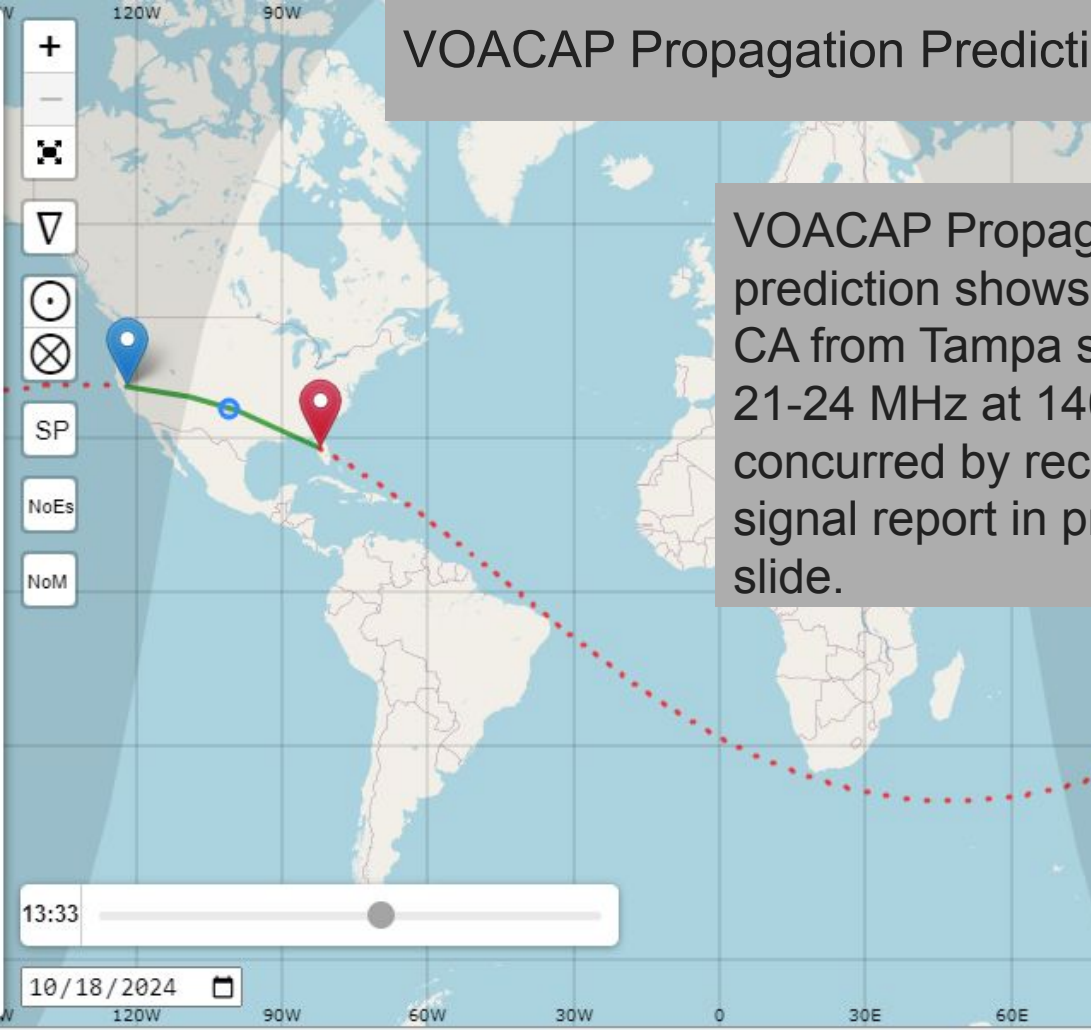
6 mins	7 MHz
10 mins	14 MHz
3 mins	18 MHz
1 mins	21 MHz
1 mins	24 MHz
1 mins	28 MHz

Received signal reports indicate strongest signal near main lobe with weaker signals demonstrating MUF on west coast

VOACAP Propagation Predicti



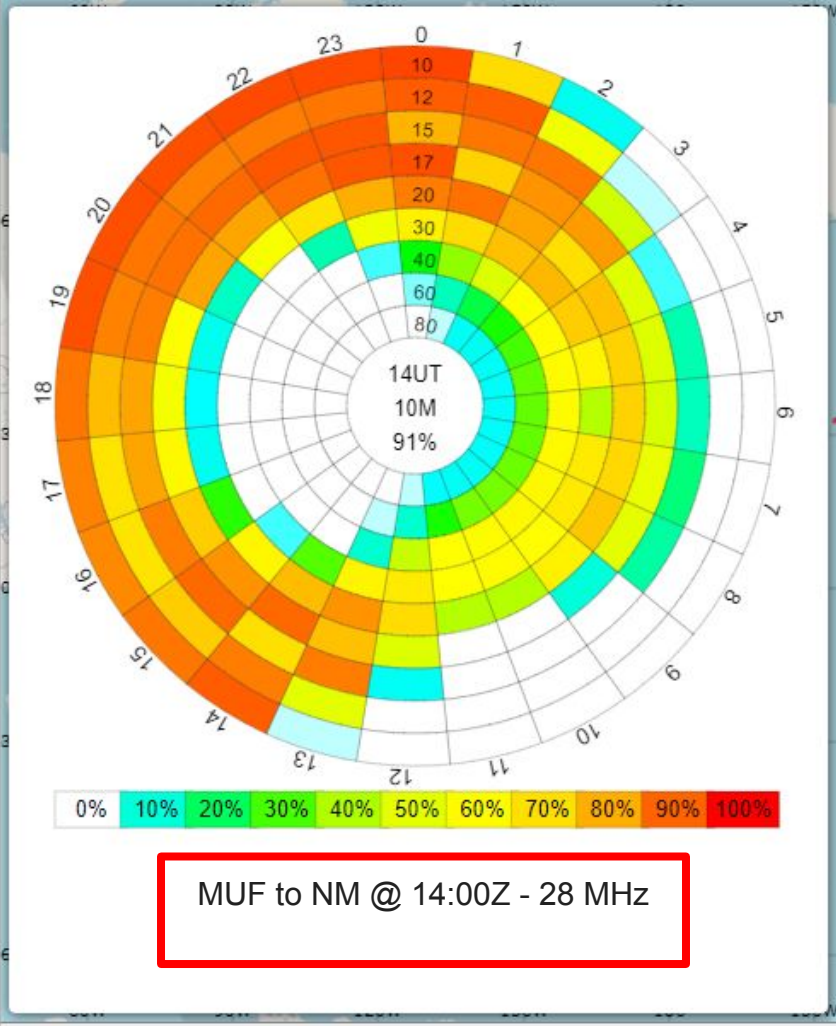
MUF to CA @ 14:00Z - 24 MHz



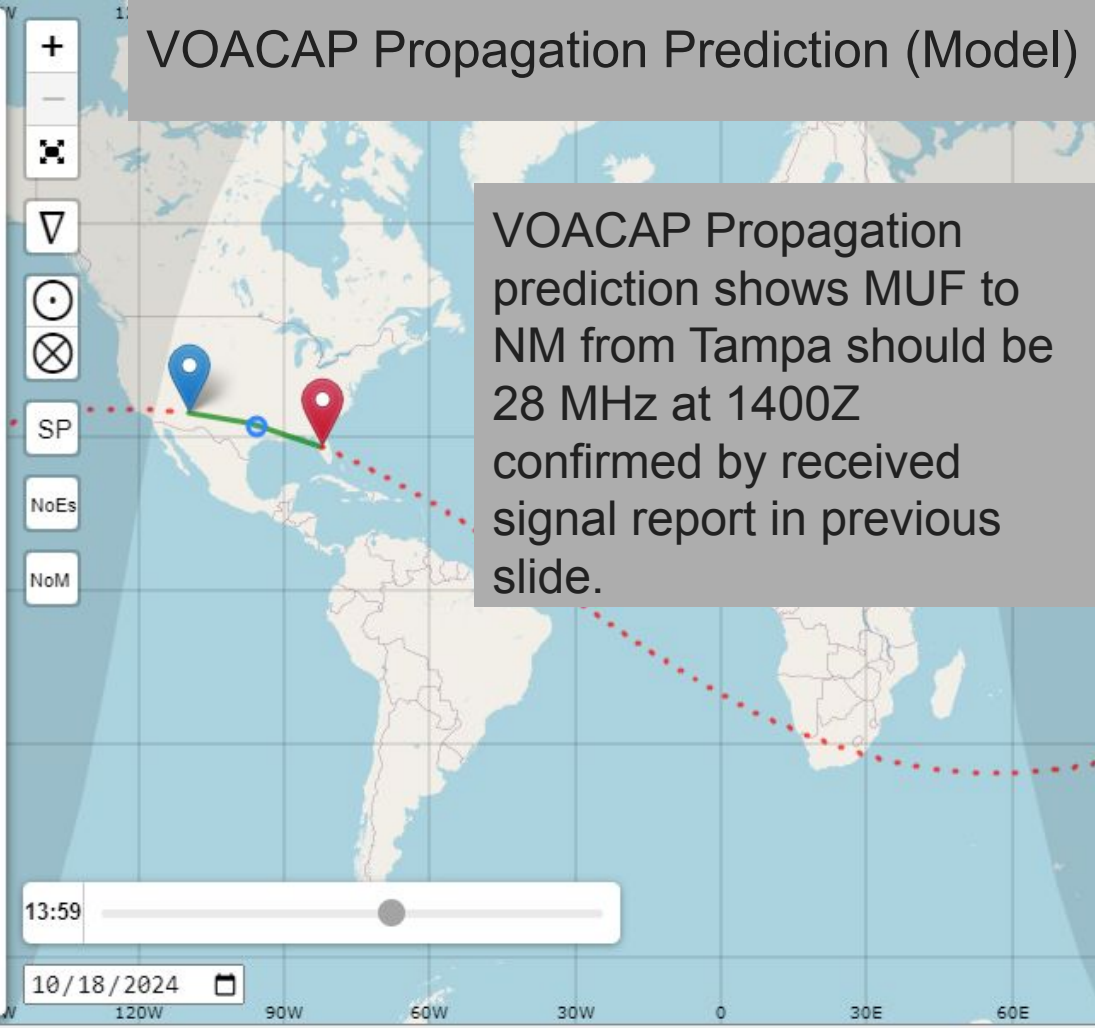
VOACAP Propag
prediction shows
CA from Tampa s
21-24 MHz at 14
concurred by rec
signal report in p
slide.

TX: 28.30, -82.27 | RX: 38.82, -122.01 | Short: 3837 km — 2384 mi | 298° — 96° | Mid: 35.2061, -100.8819 | Long: 36171 km — 22476 mi | 118° — 276° | Mid: -35.2061, 79.1181

VOACAP Propagation Prediction (Model)



MUF to NM @ 14:00Z - 28 MHz



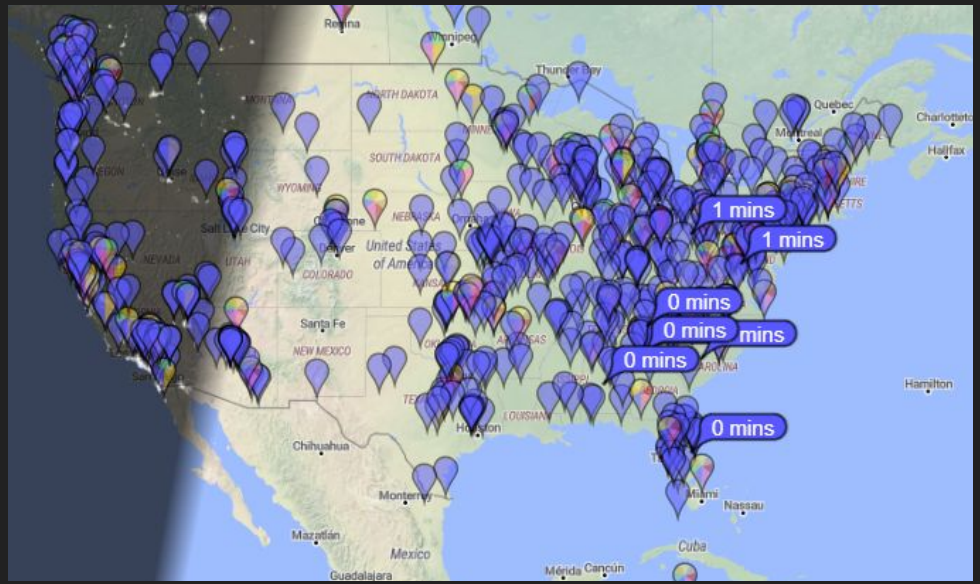
VOACAP Propagation prediction shows MUF to NM from Tampa should be 28 MHz at 1400Z confirmed by received signal report in previous slide.

TX: 28.30, -82.27 | RX: 34.31, -109.69 | Short: 2685 km — 1668 mi | 291° — 97° | Mid: 32.0494, -95.5343 | Long: 37323 km — 23192 mi | 111° — 277° | Mid: -32.0494, 84.4657

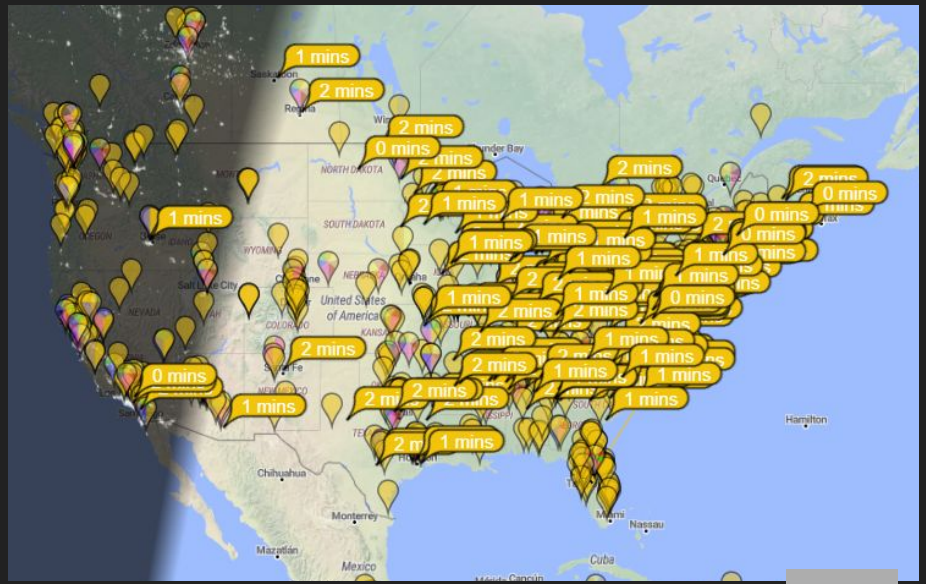
Signal Reports by Frequency (Measured)

500’ Sloped Wire // 35’ // 20° // Freq. Comparison // 0945L

7 MHz



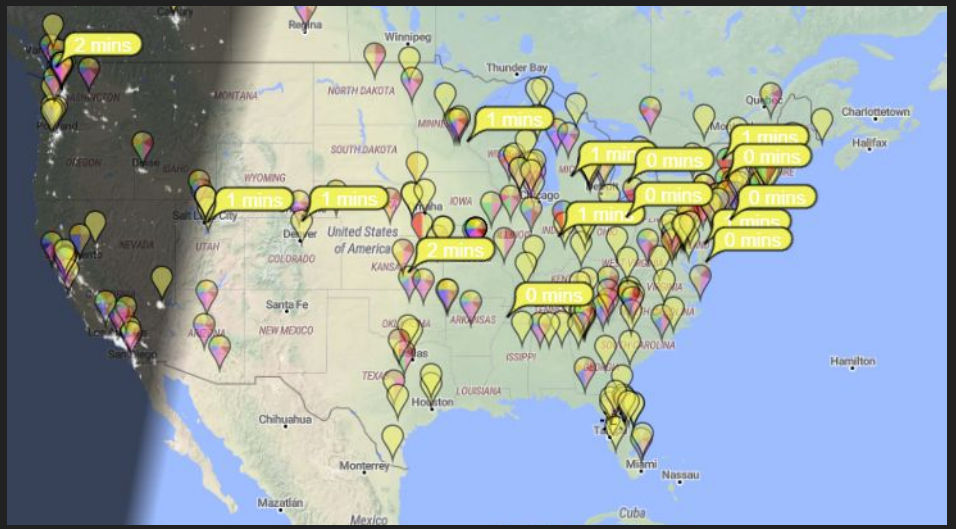
14 MHz



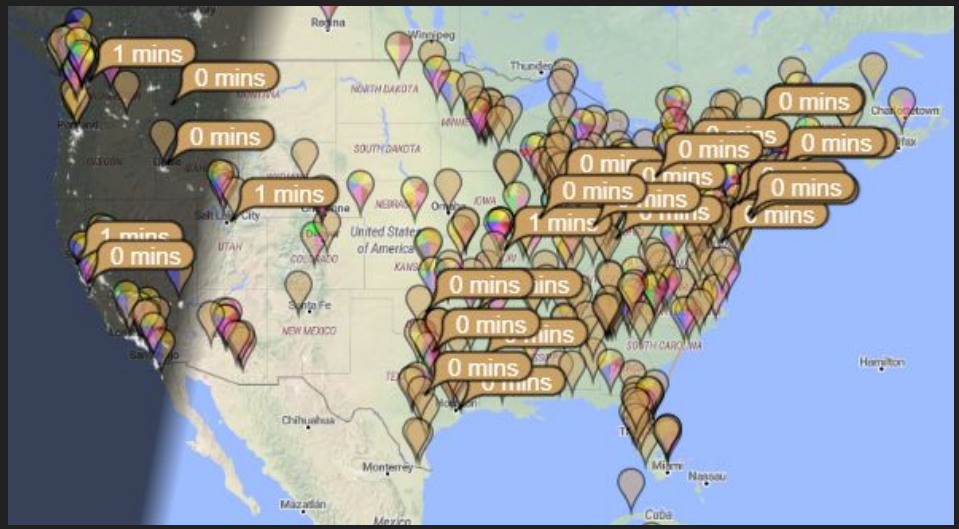
Signal Reports by Frequency (Measured)

500’ Sloped Wire // 35’ // 20° // Freq. Comparison // 0950L

18 MHz



21 MHz

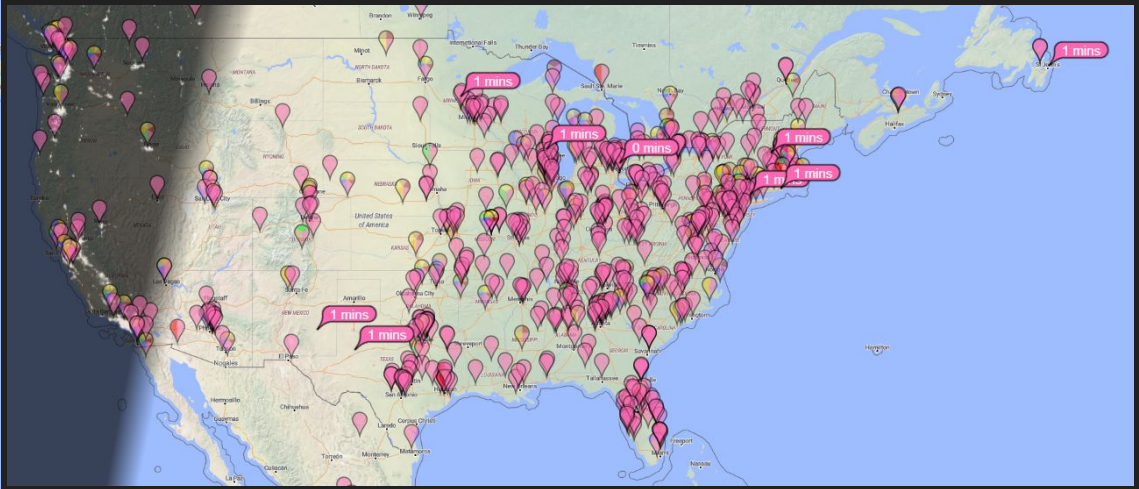


Signal Reports by Frequency (Measured)

500’ Sloped Wire // 35’ // 20° // Freq. Comparison // 0955L

24 MHz

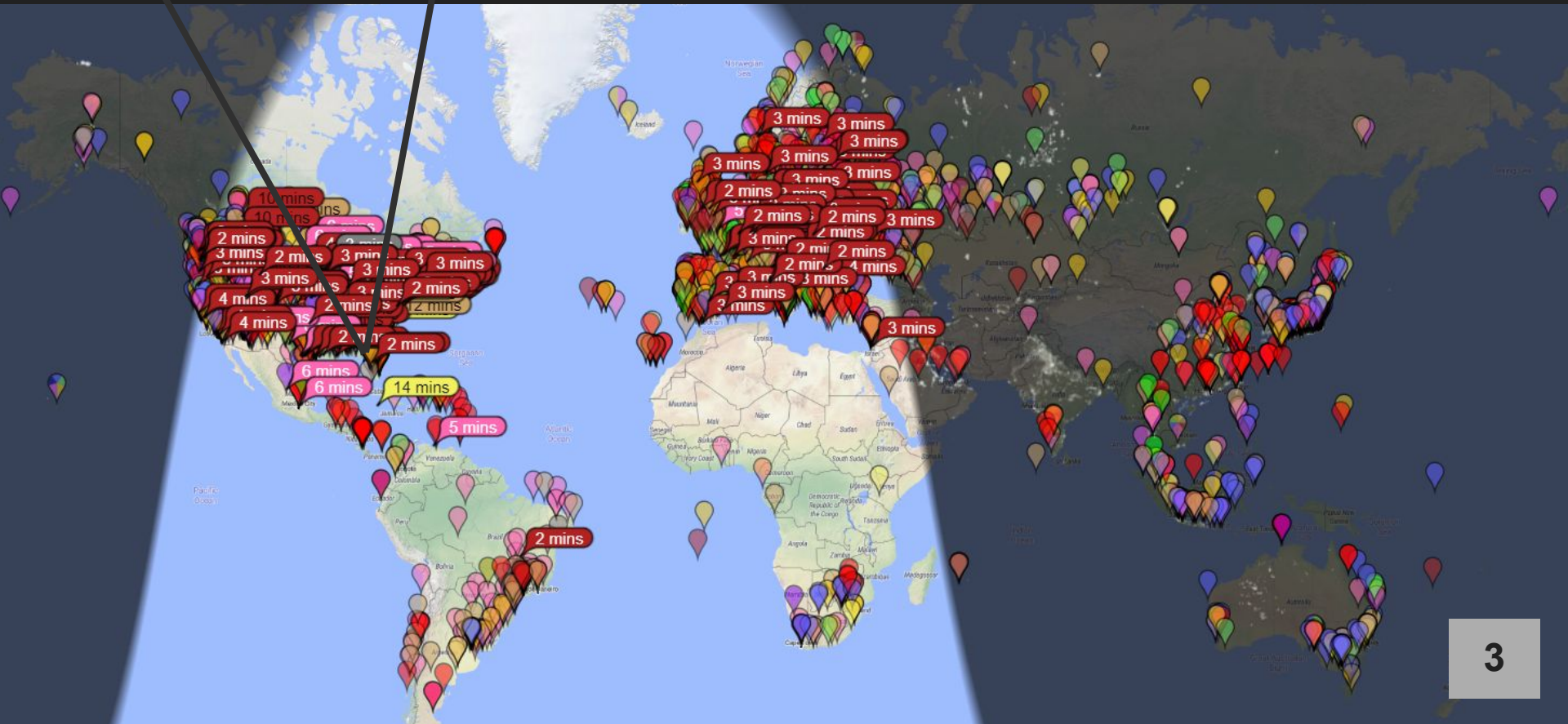
28 MHz



N Longwire (500’, 20 AWG Kevlar)

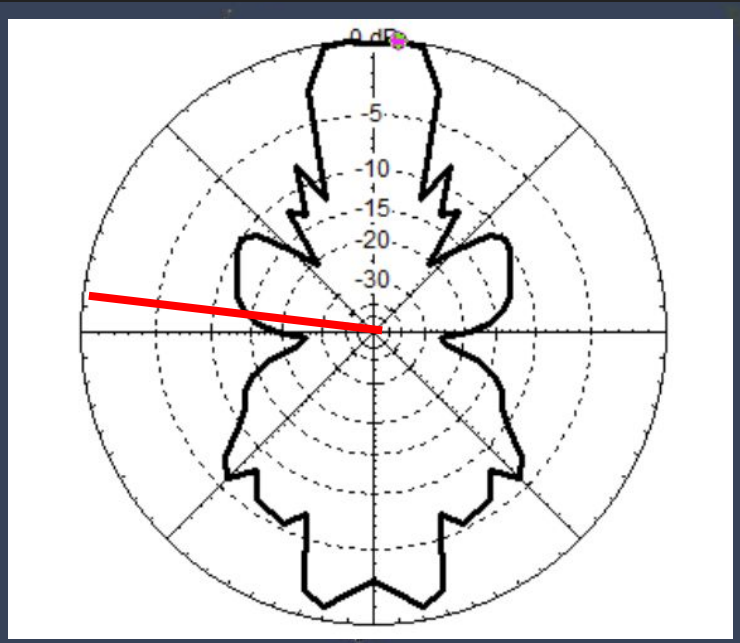
No change to VSWR Model, Measured VSWR, or gain modeling.

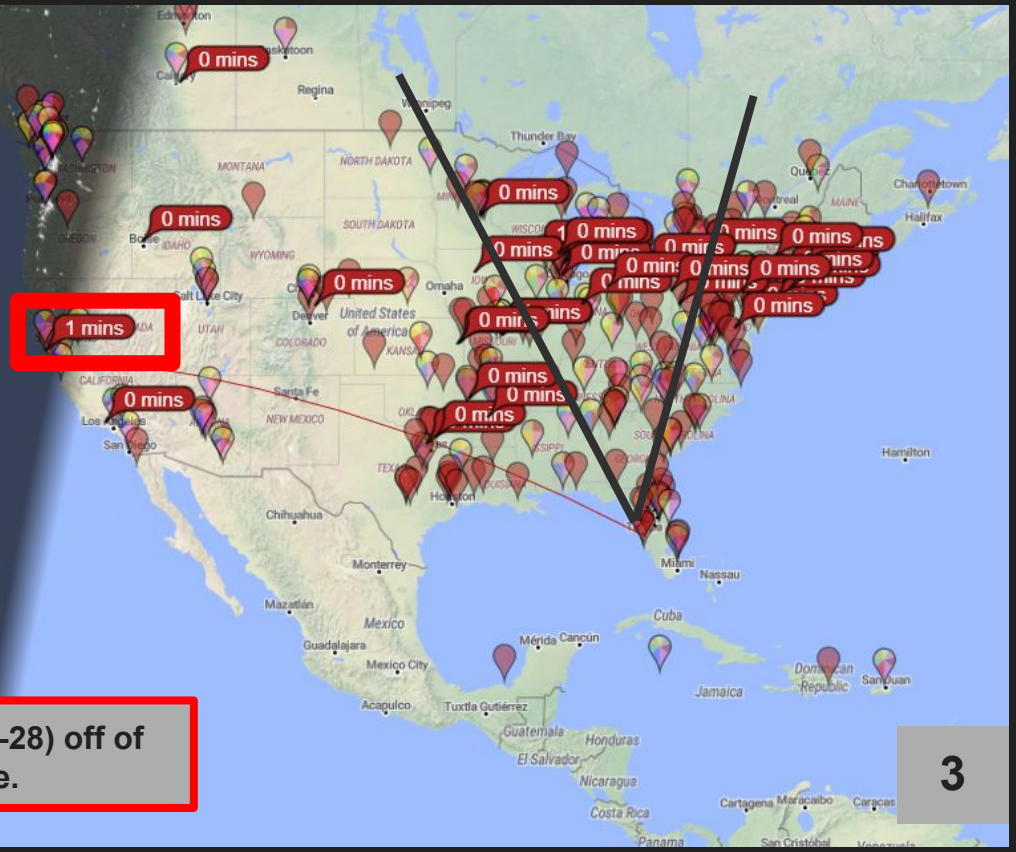
Combined Signal Reports (Measured)
500’ Sloped Wire // 35’ // 350° // 40 W // 24 MHz // 1030L



Signal Reports by Frequency (Measured)

500’ Sloped Wire // 35’ // 350° // 24 MHz // 1020L



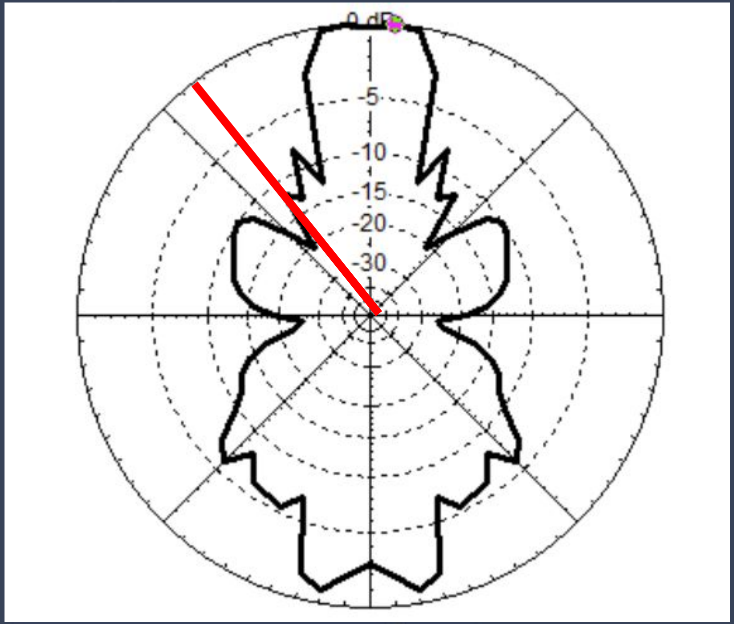


Rx at Fri, 18 Oct 2024 14:18:30 GMT
From N0JMP by KPH2 in California, United States Loc CM88mc
Frequency: 24.915.756 MHz (12m), FT8 -28dB
Distance: 2441 miles bearing 297°
Using: N1DQ-Importer-KA9Q-Radio
Antenna: TCI-530

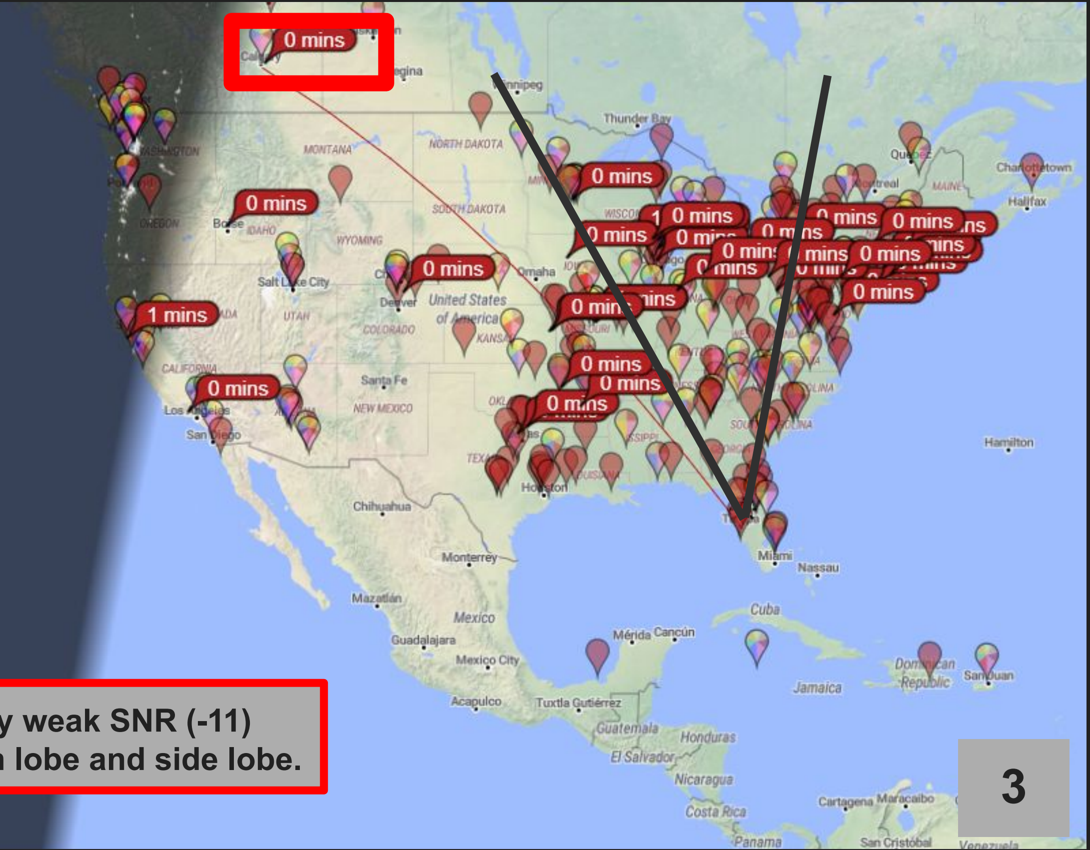
Very weak SNR (-28) off of side lobe.

Signal Reports by Frequency (Measured)

500’ Sloped Wire // 35’ // 350° // 24 MHz // 1020L



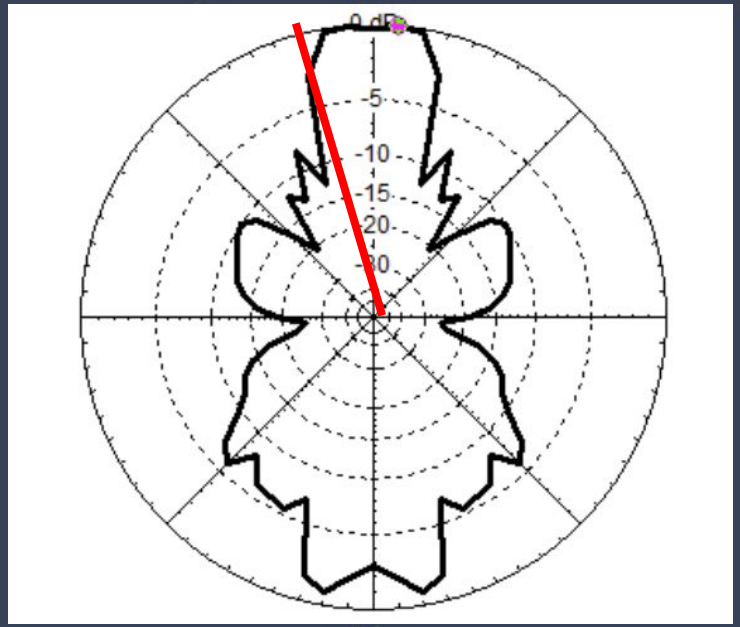
Rx at Fri, 18 Oct 2024 14:18:41 GMT
From N0JMP by VE6VC in Alberta, Canada Loc DO30av96
Frequency: 24.915.759 MHz (12m), FT8 -11dB
Distance: 3688 km bearing 322°
Using: WSJT-X v2.6.1 6b6d74



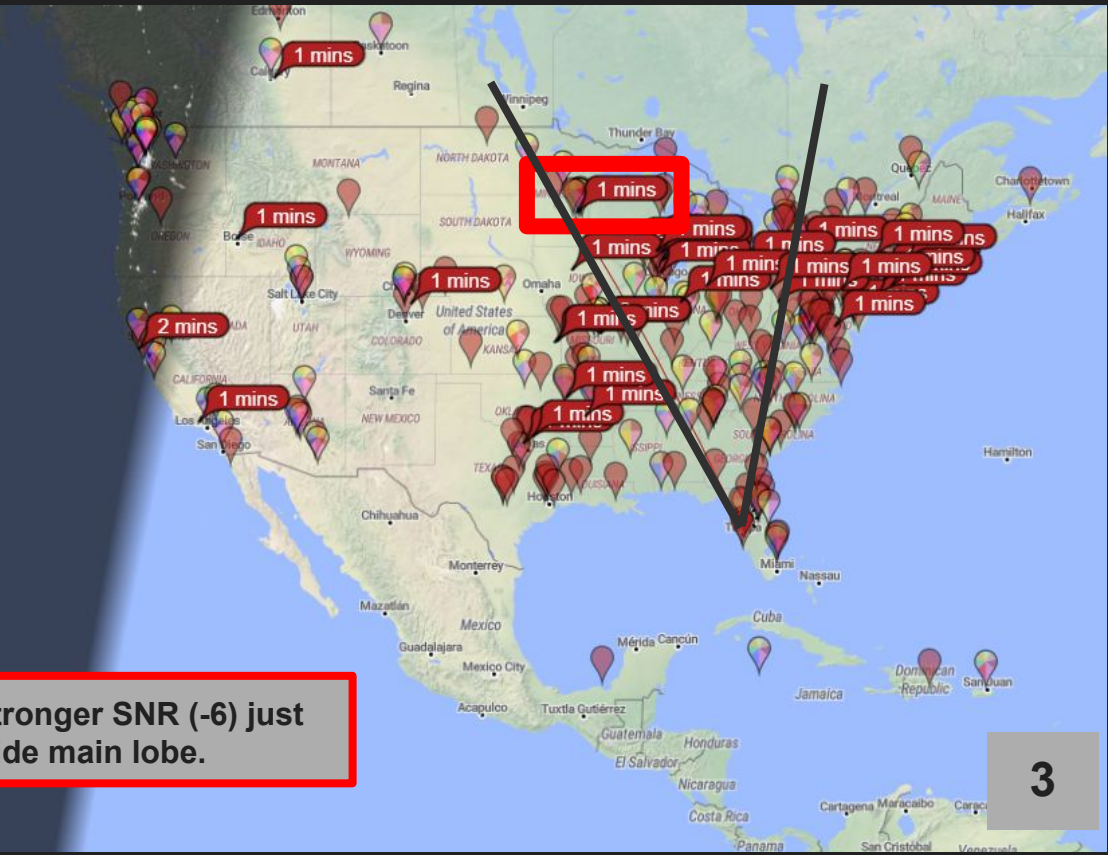
Moderately weak SNR (-11) between main lobe and side lobe.

Signal Reports by Frequency (Measured)

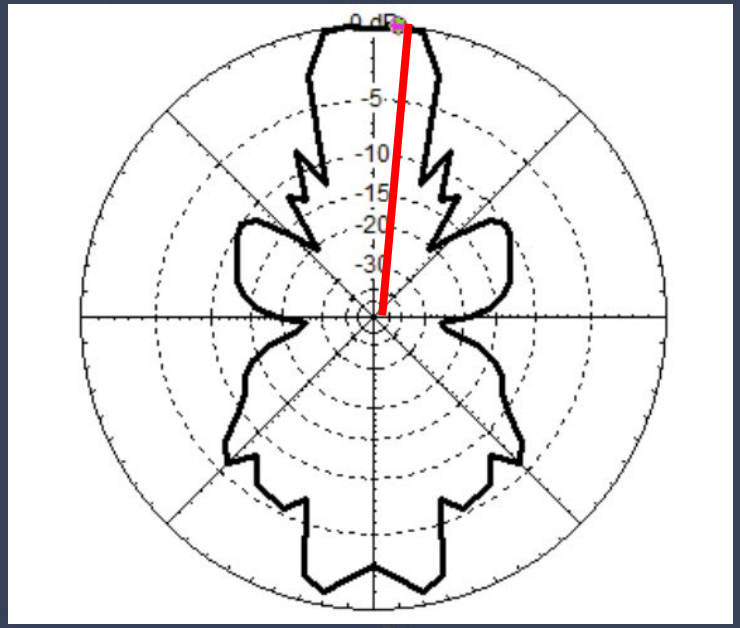
500’ Sloped Wire // 35’ // 350° // 24 MHz // 1020L

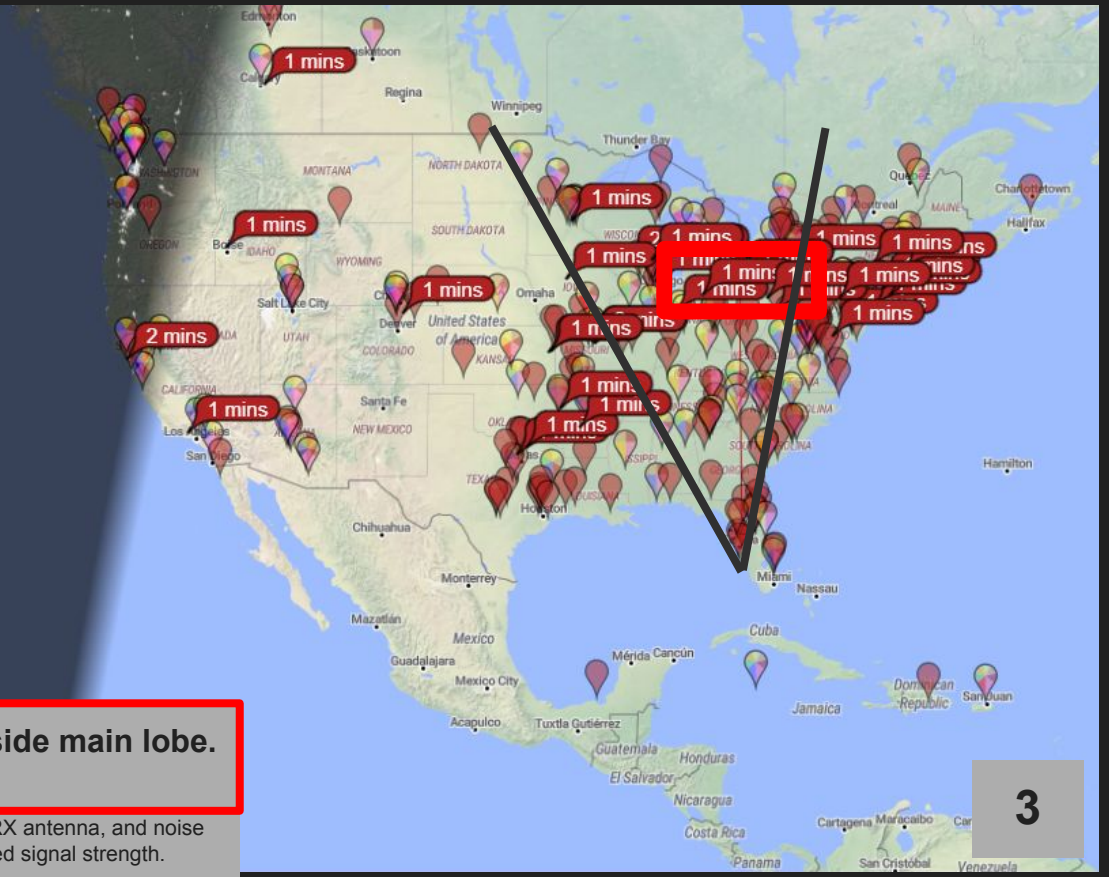


Slightly stronger SNR (-6) just inside main lobe.



500’ Sloped Wire // 35’ // 350° // 24 MHz // 1020L



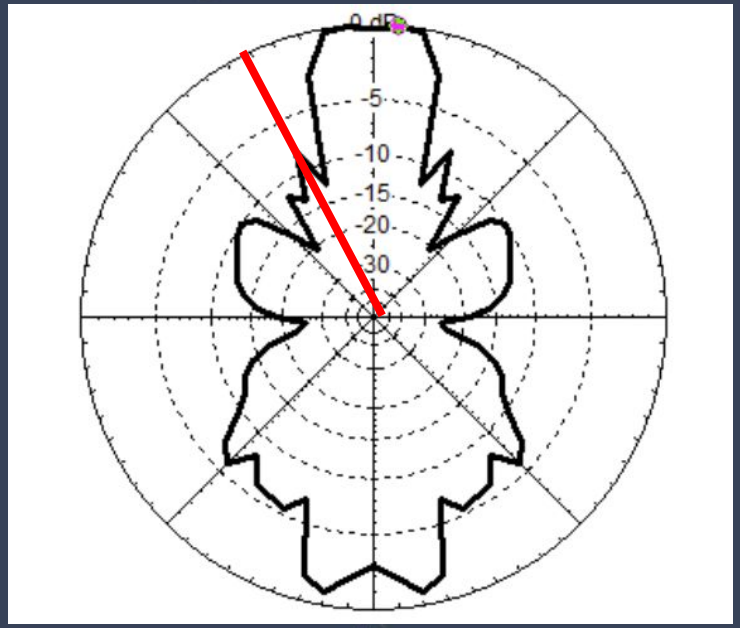


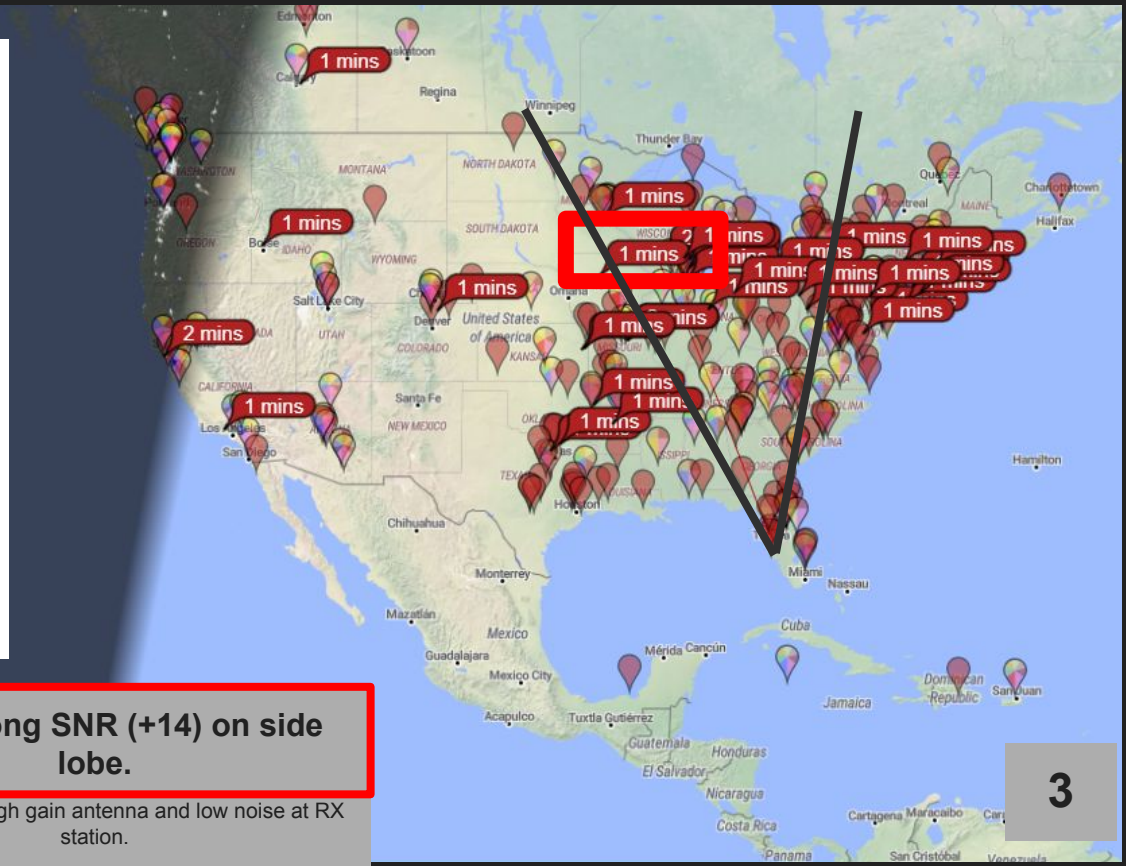
Rx at Fri, 18 Oct 2024 14:18:42 GMT
From N0JMP by VE3CRO in Canada Loc EN82sg84
Frequency: 24.915.795 MHz (12m), FT8 -1dB
Distance: 1607 km bearing 359°
Using: WSJT-X v2.6.1 6b6d74

Strong SNR (-1) inside main lobe.

*Remember, take off angle. RX antenna, and noise also play a role in received signal strength.

500’ Sloped Wire // 35’ // 350° // 24 MHz // 1020L





Rx at Fri, 18 Oct 2024 14:18:30 GMT
From N0JMP by K9IMM in Wisconsin, United States Loc EN52cv
Frequency: 24.915.907 MHz (12m), FT8, +14dB
Distance: 1123 miles bearing 340°
Using: CWSL_DIGI 0.88
Antenna: 5 el @ 95'

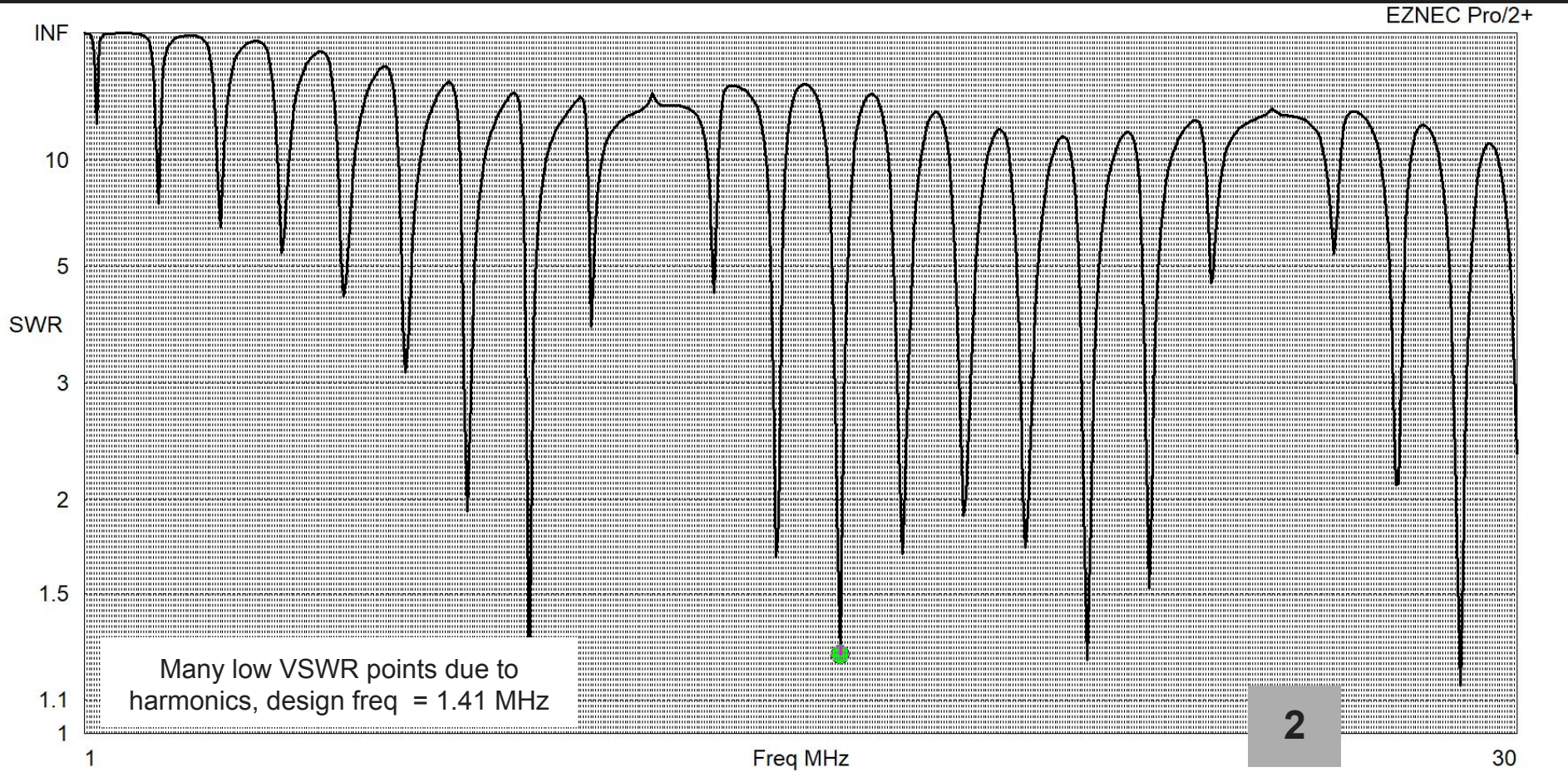
Very strong SNR (+14) on side lobe.

*Likely due to high gain antenna and low noise at RX station.

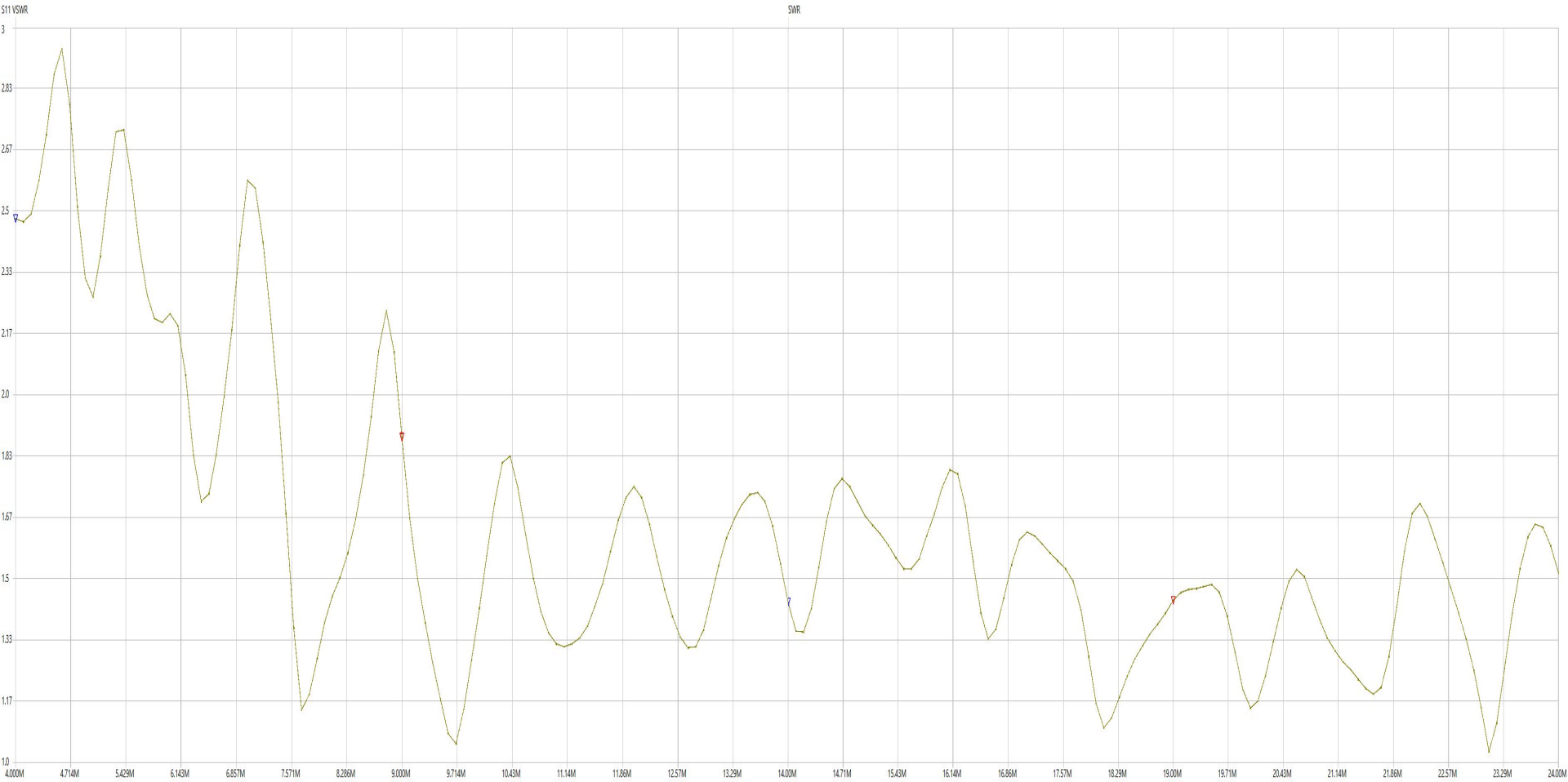
NW Longwire (350’, 14 AWG)

Shortened due to space constraints, results in slightly wider beam width and slightly lower gain.

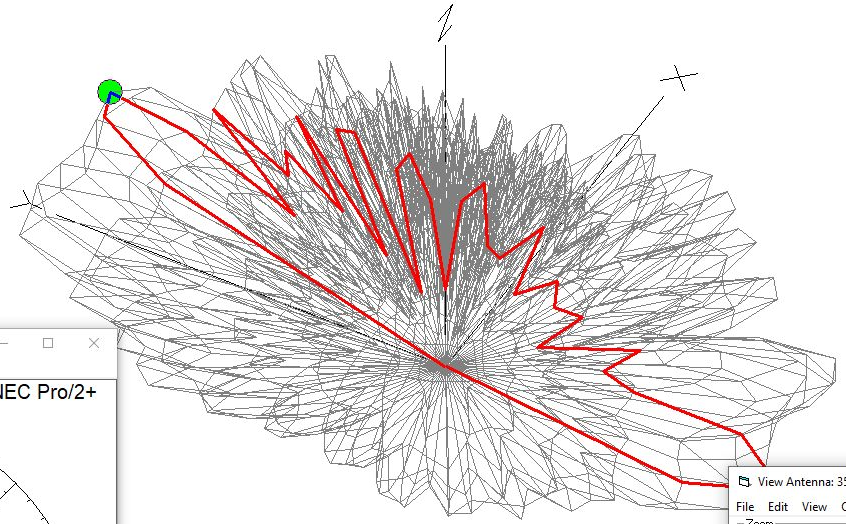
Model VSWR (350’)

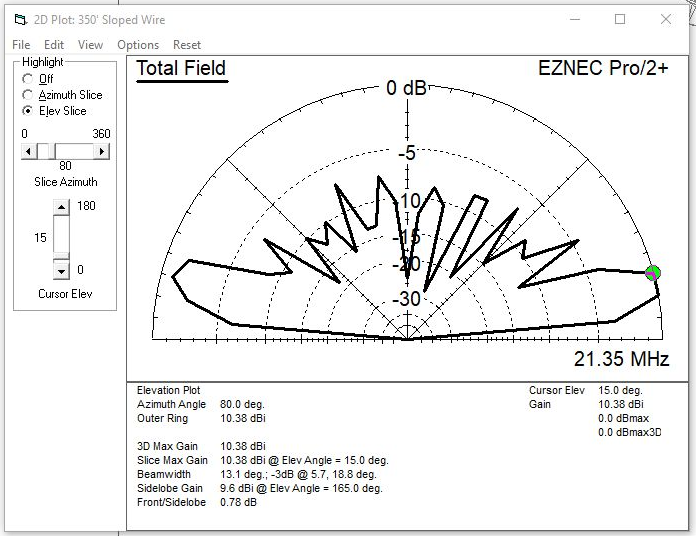


Measured VSWR (350’)

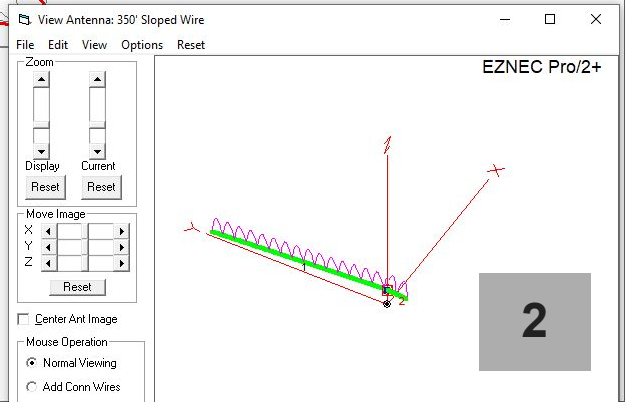


21.35 MHz Elevation Gain (350’)

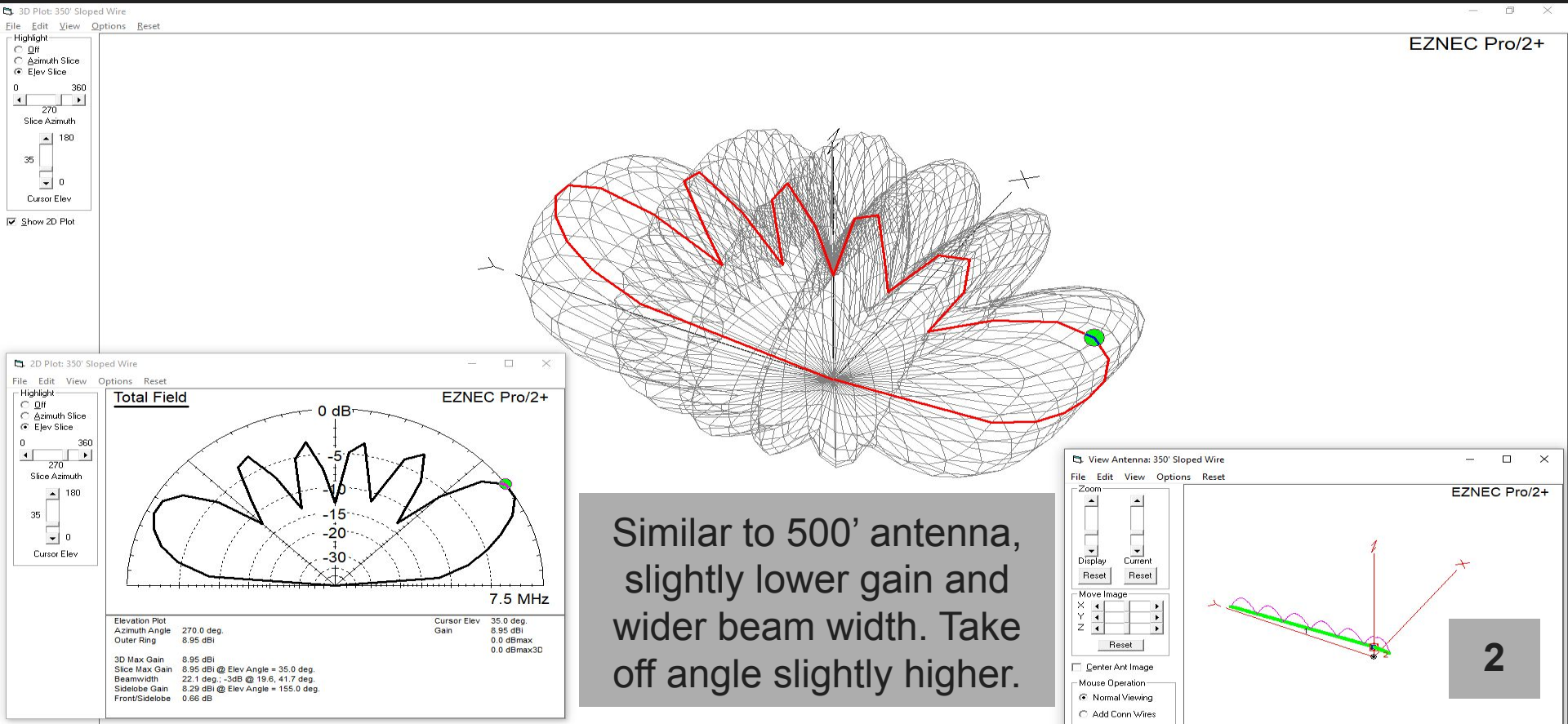




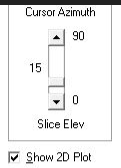
Similar to 500’ antenna, slightly lower gain and wider beam width.

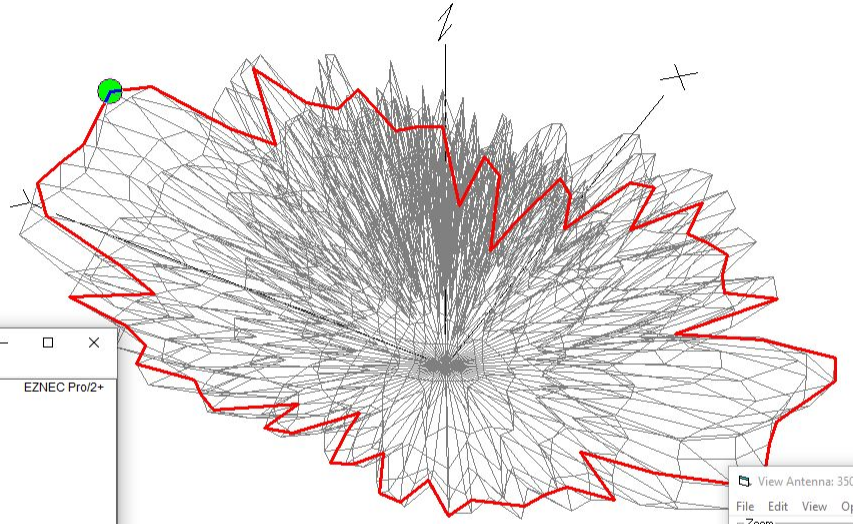


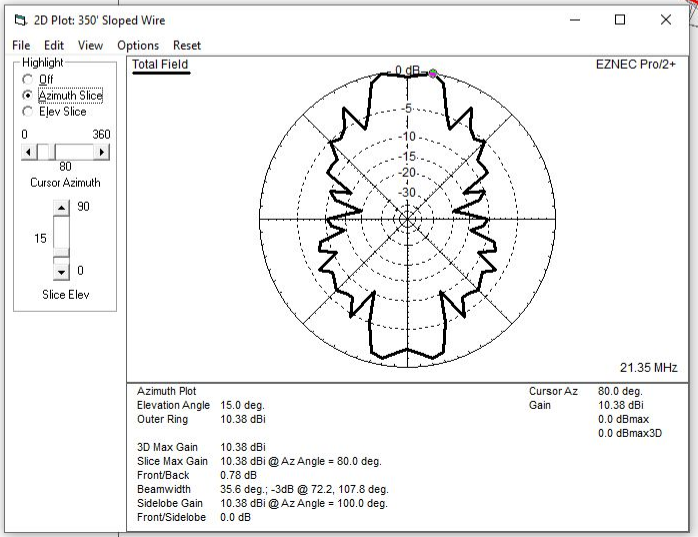
7.5 MHz Elevation Gain (350’)



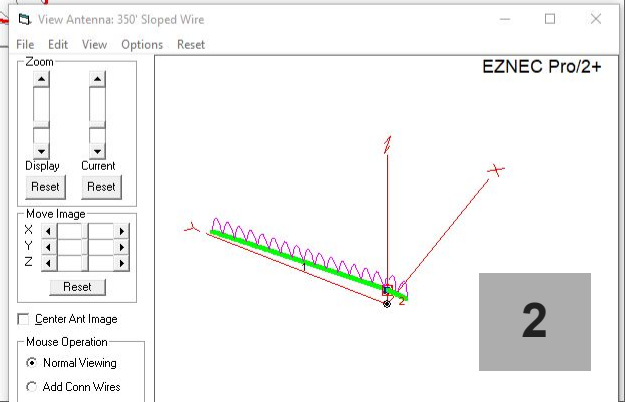
21.35 MHz Azimuth Gain (350’)



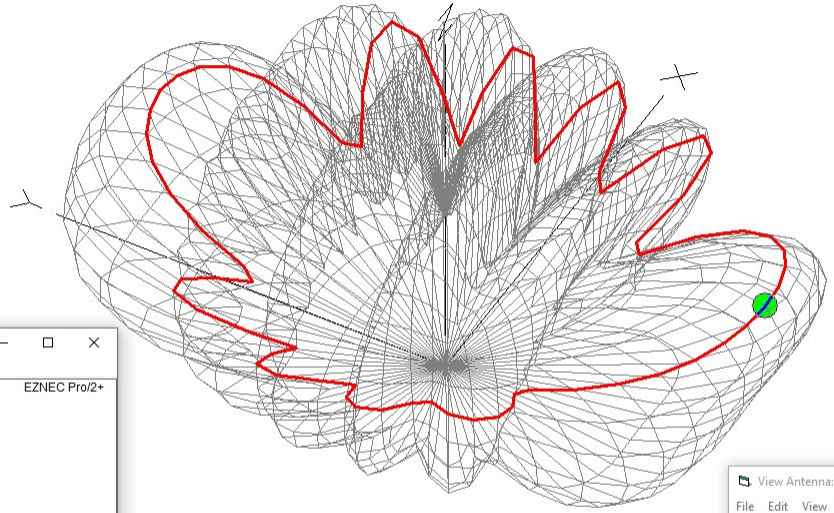


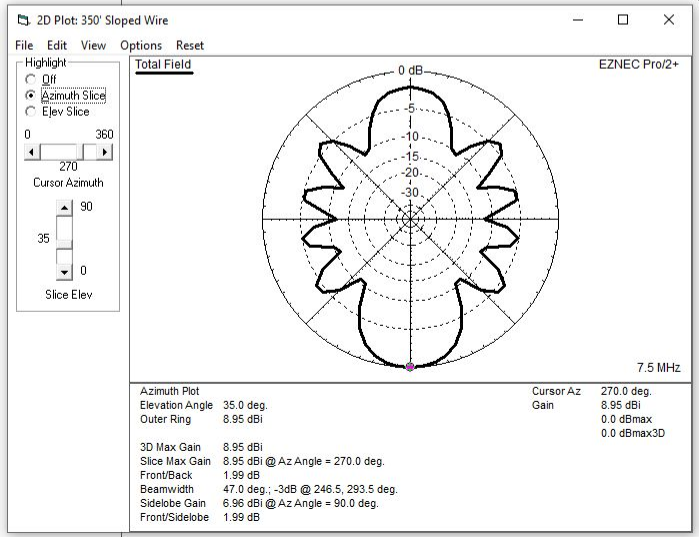


Similar to 500’ antenna, slightly lower gain and wider beam width.

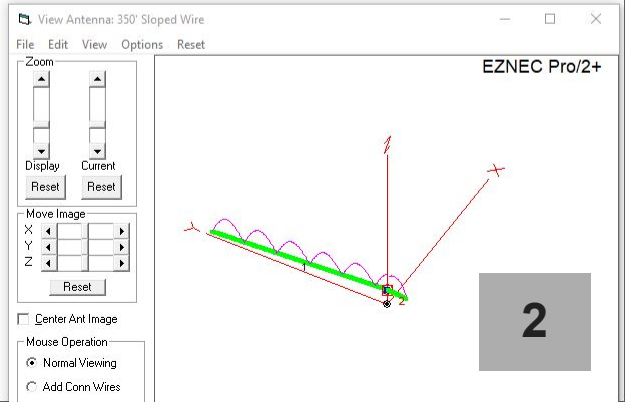


7.5 MHz Azimuth Gain (350’)

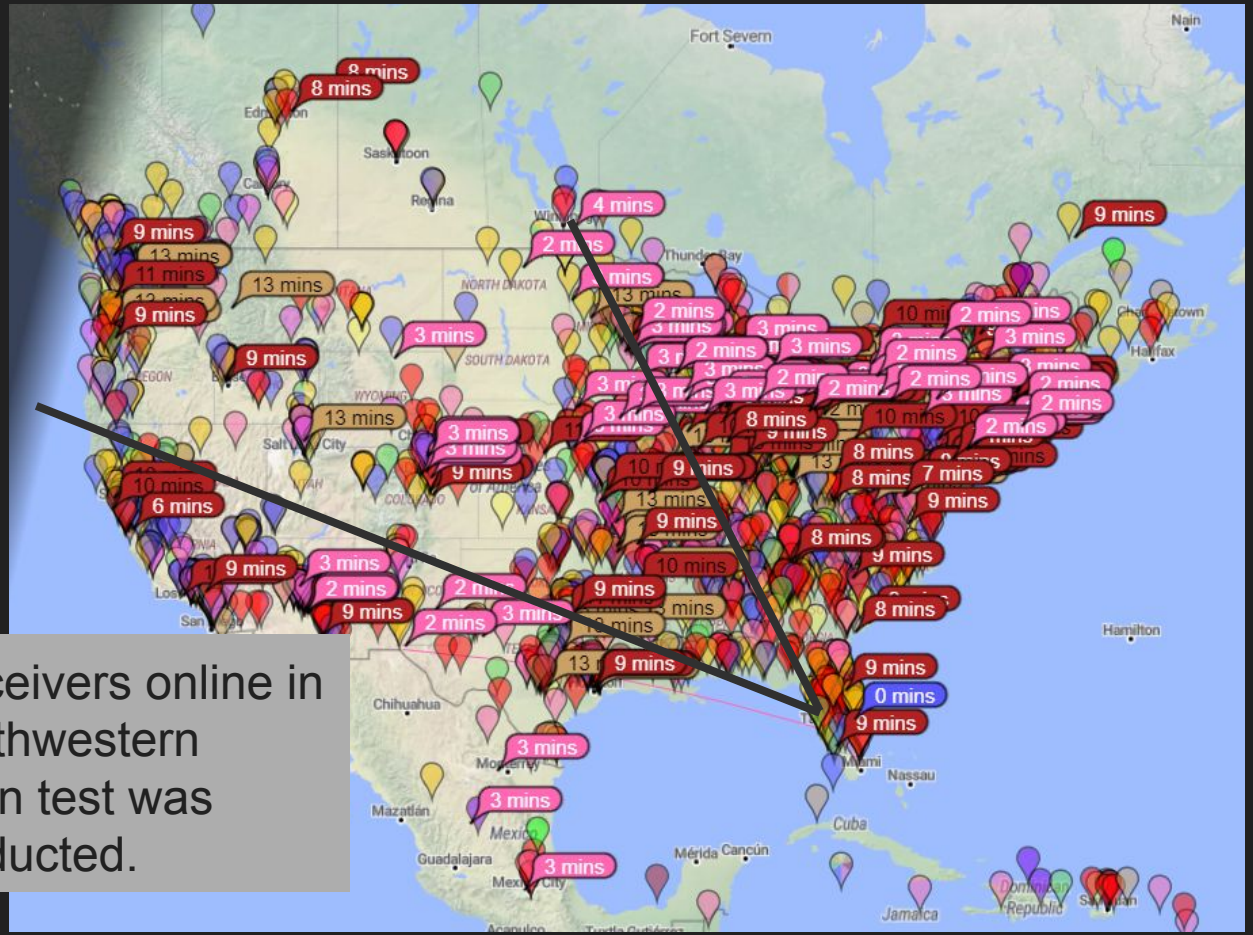




Similar to 500’ antenna, slightly lower gain and wider beam width. Take off angle slightly higher.



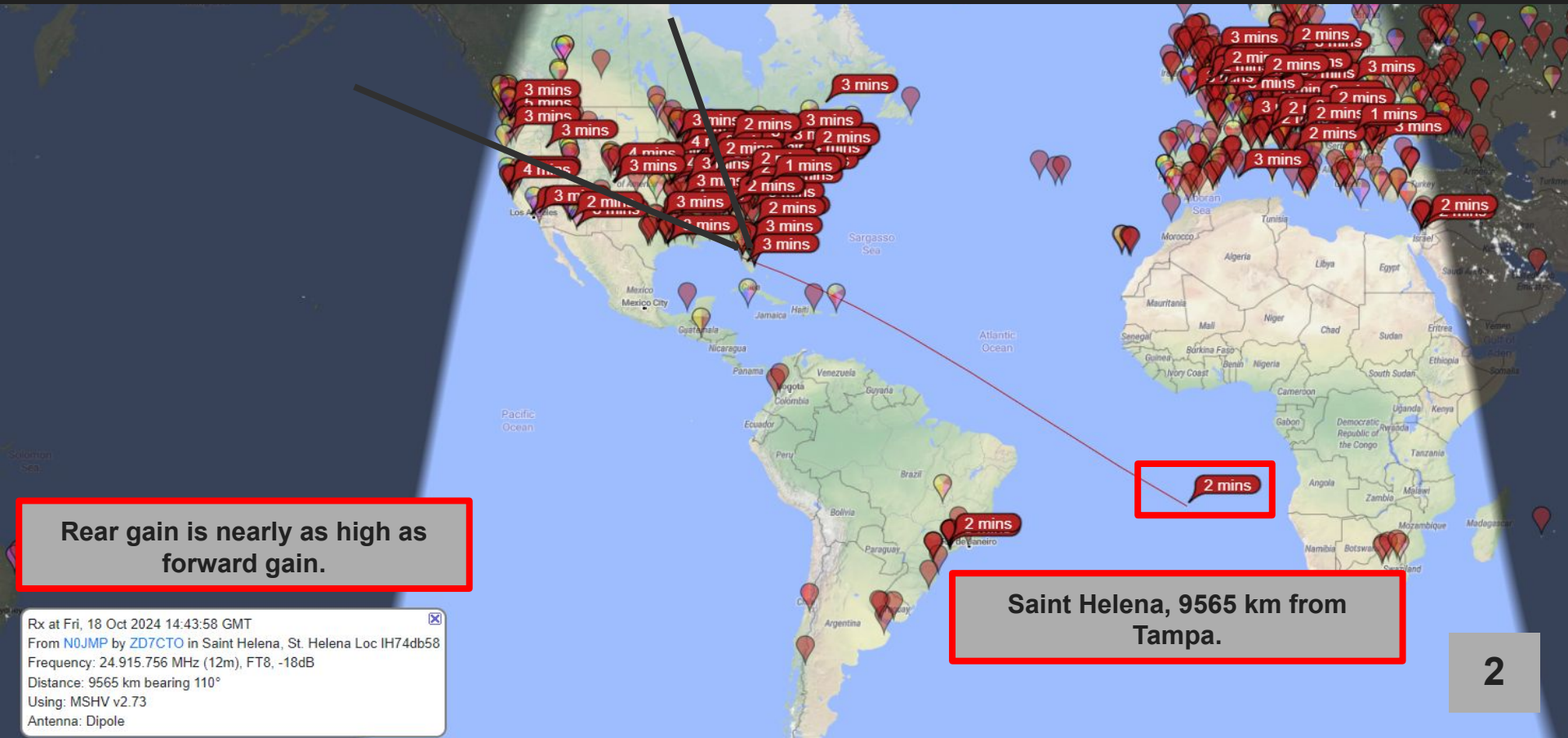
Combined Signal Reports // 350’ Sloped Wire // 35’ // 320° // 1050L



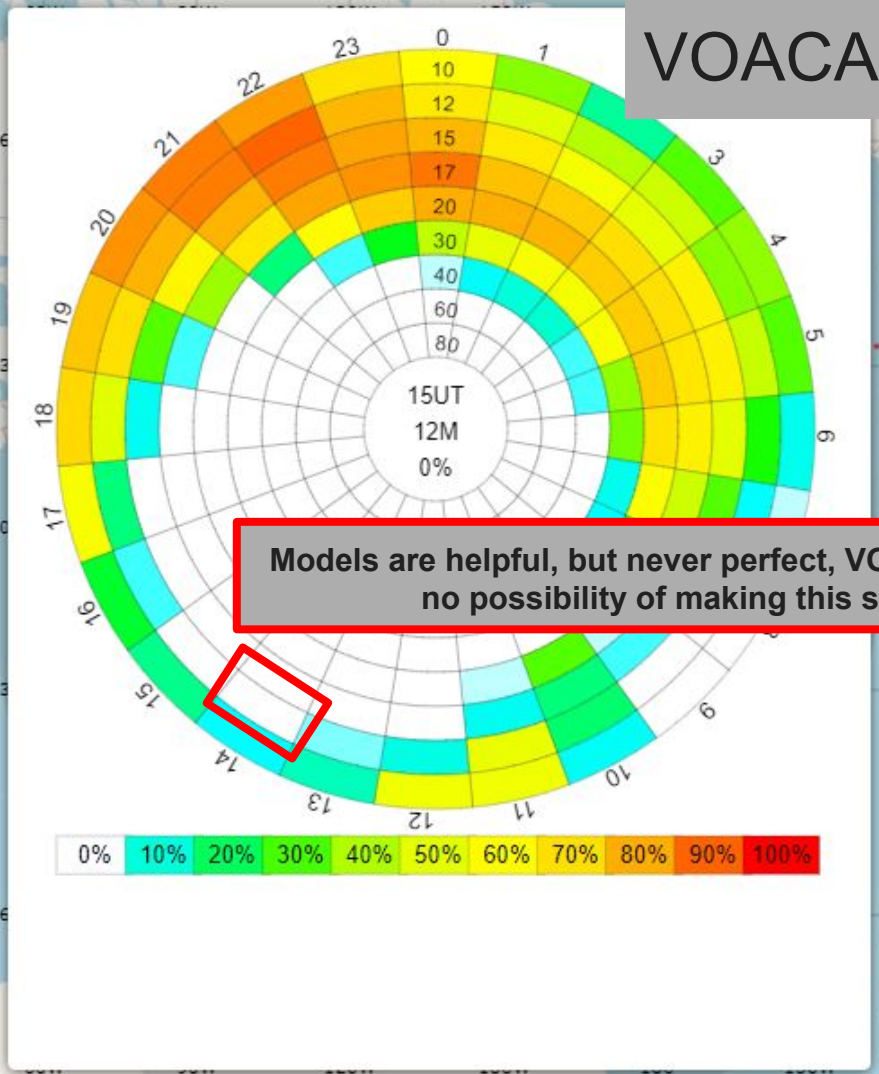
6 mins	7 MHz
10 mins	14 MHz
3 mins	18 MHz
1 mins	21 MHz
1 mins	24 MHz
1 mins	28 MHz

Not many receivers online in the northwestern US when test was conducted.

Signal Reports by Frequency (Measured)
350’ Sloped Wire // 35’ // 320° // 40 W // 24 MHz // 1045L



VOACAP Propagation Prediction (Model)



Models are helpful, but never perfect, VOACAP shows no possibility of making this shot.

W Longwire (24 AWG)

No change to VSWR Model, Measured VSWR, or gain modeling from other 500’ wires.

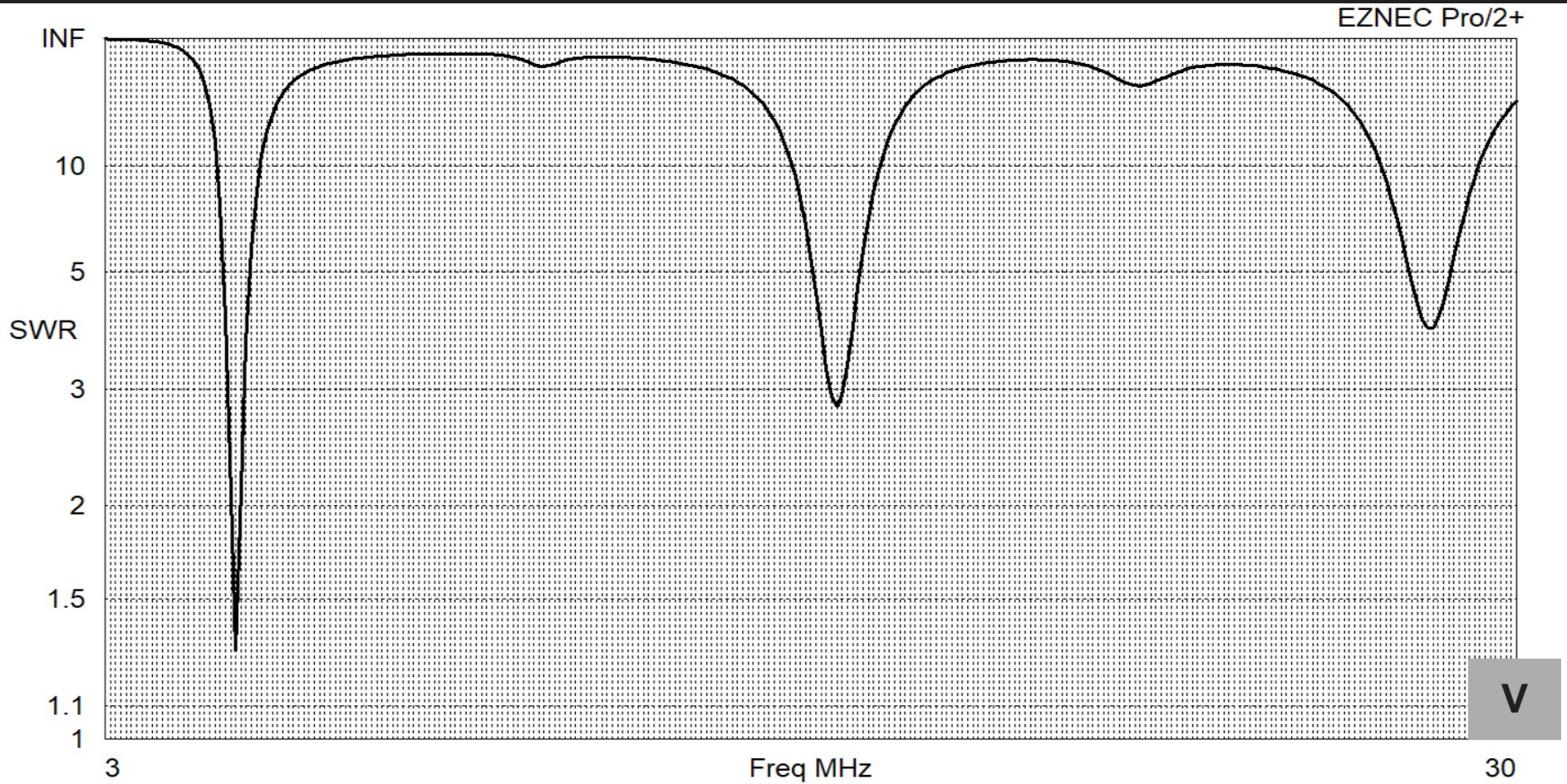
Combined Signal Reports (Measured)
500’ Sloped Wire // 35’ // 290° // 1110L

Frequency specific signal reports similar to other 500’ wires with received locations further west.

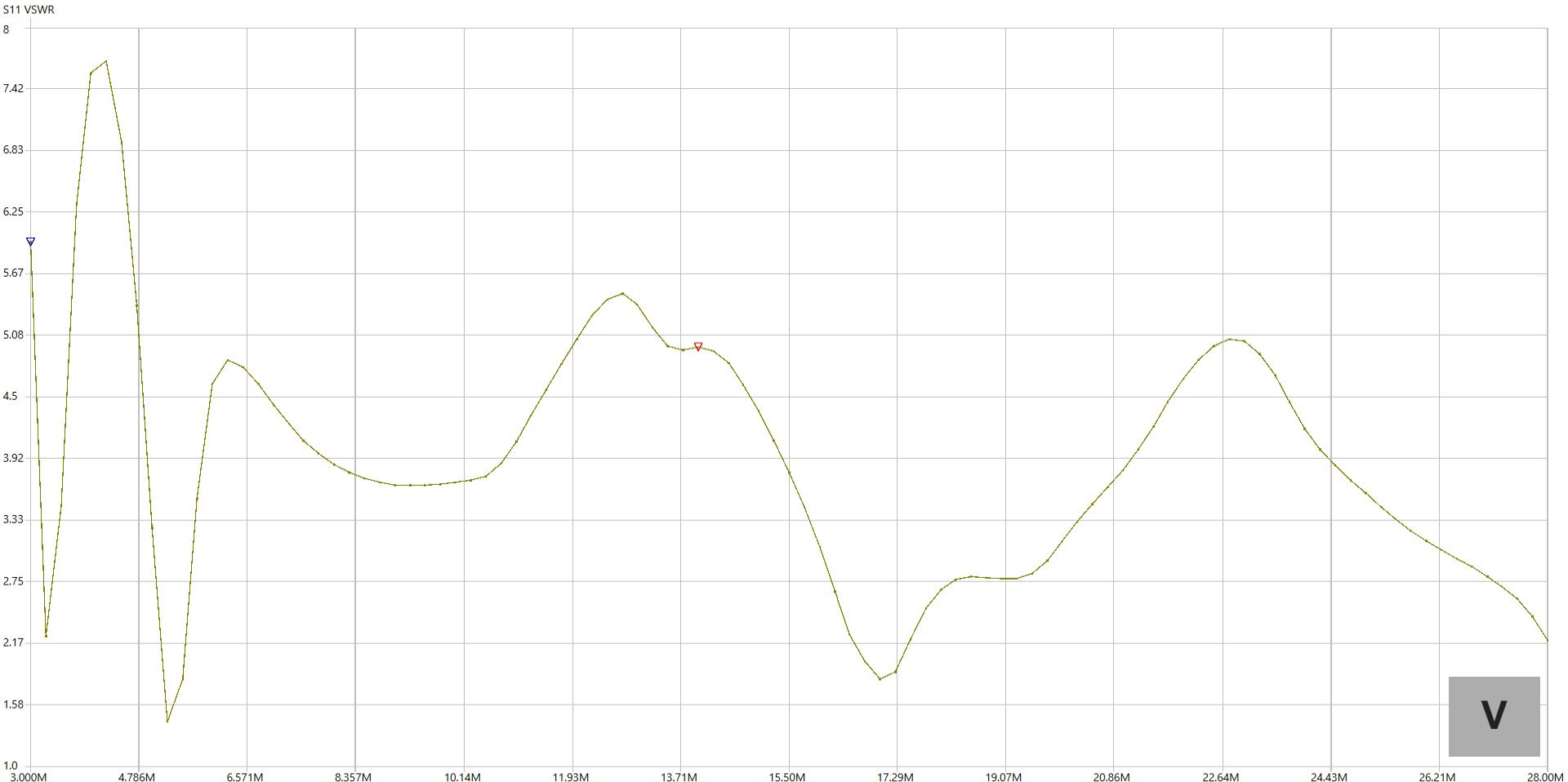
Not many receivers online in the western US when the test was conducted.

5.5 MHz Inverted V (Reference)

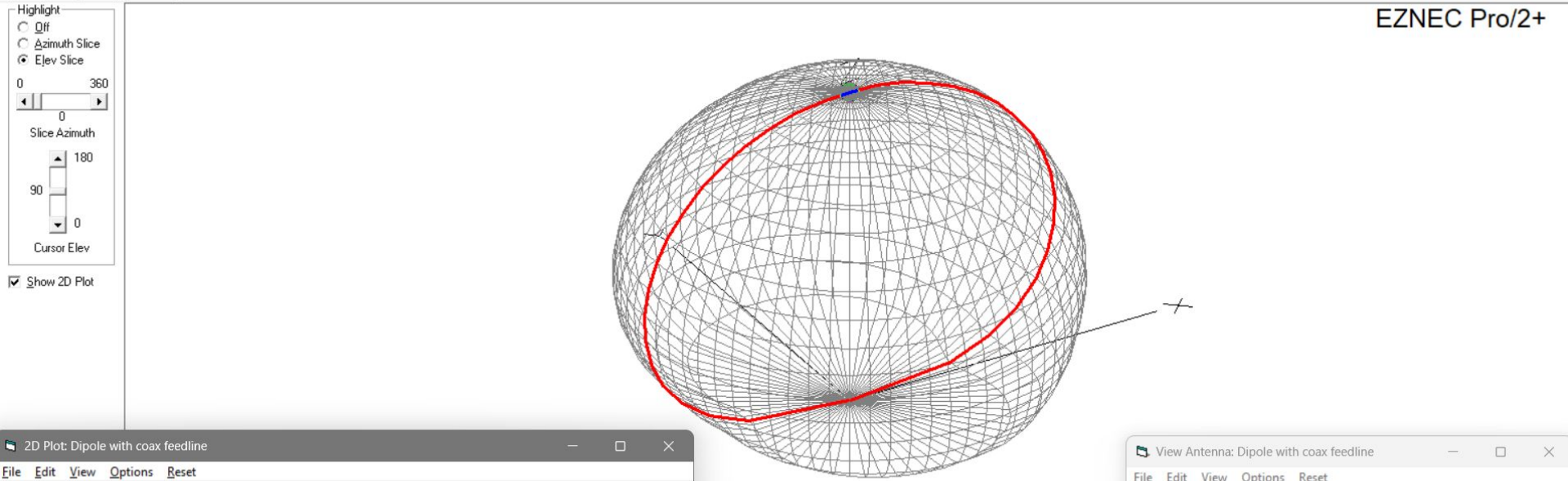
Model VSWR (5.5MHz Inverted V)

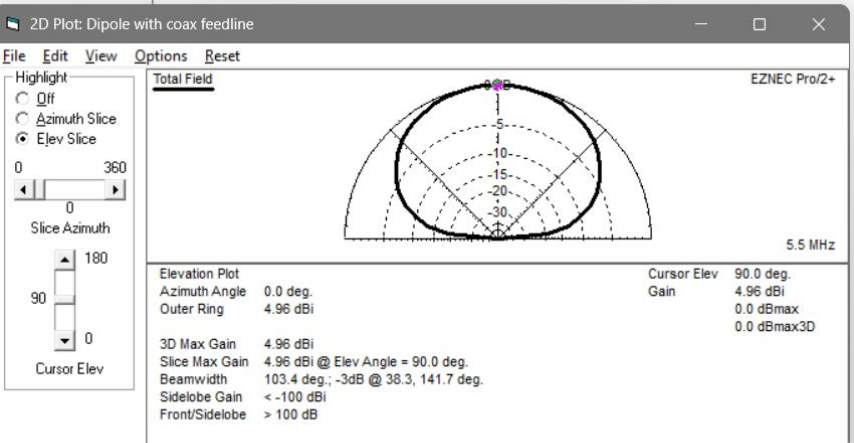


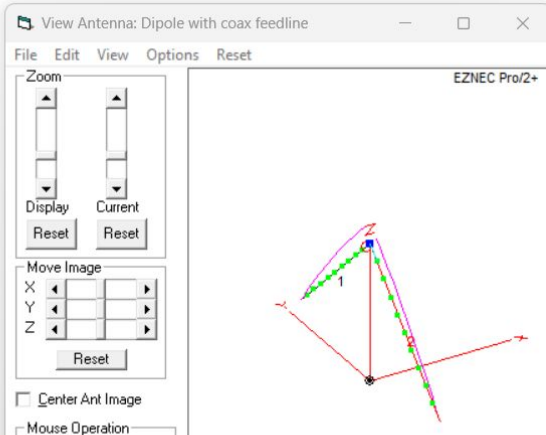
Measured VSWR (5.5MHz Inverted V)



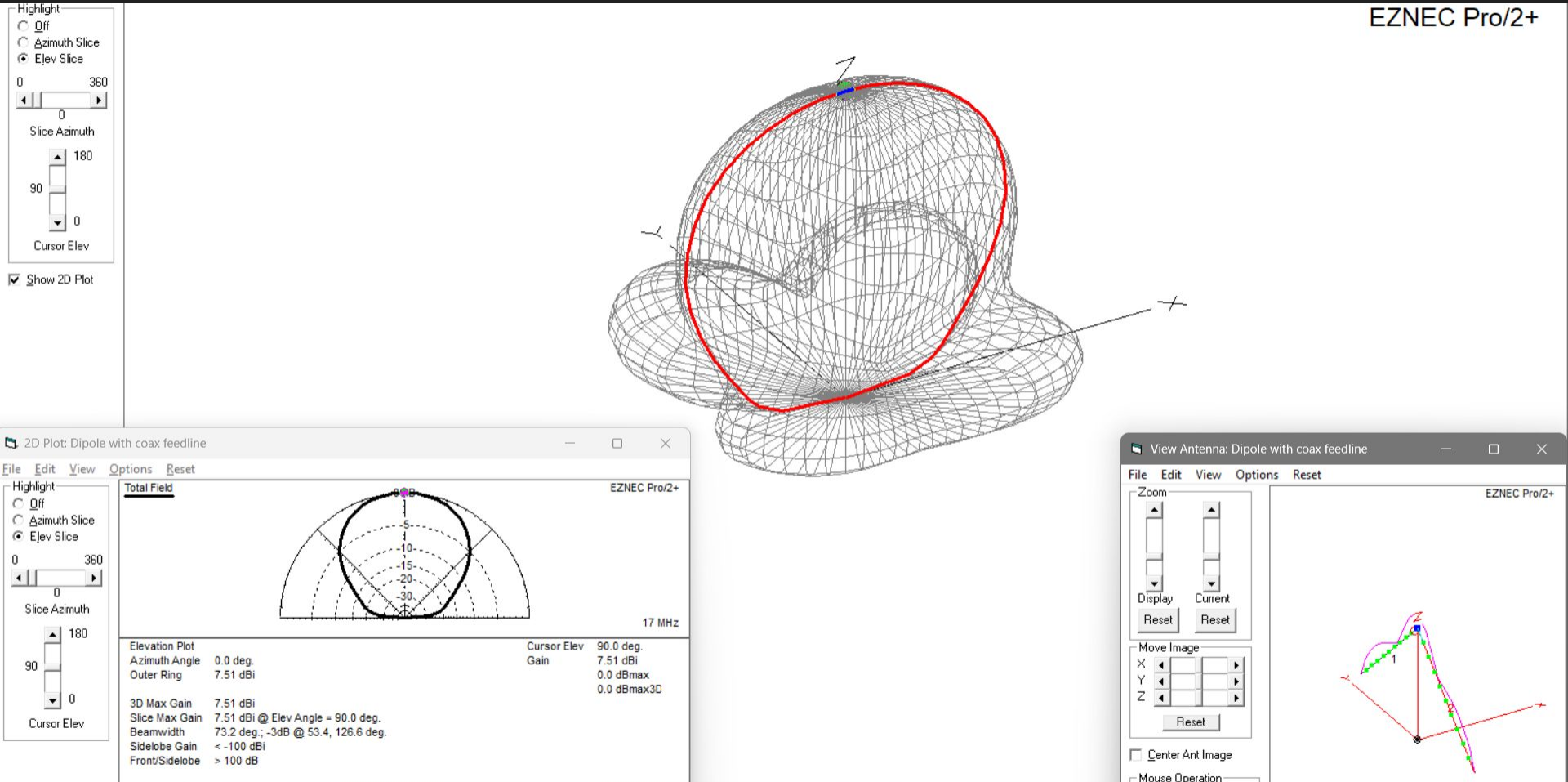
5.5MHz Elevation Gain (Model)



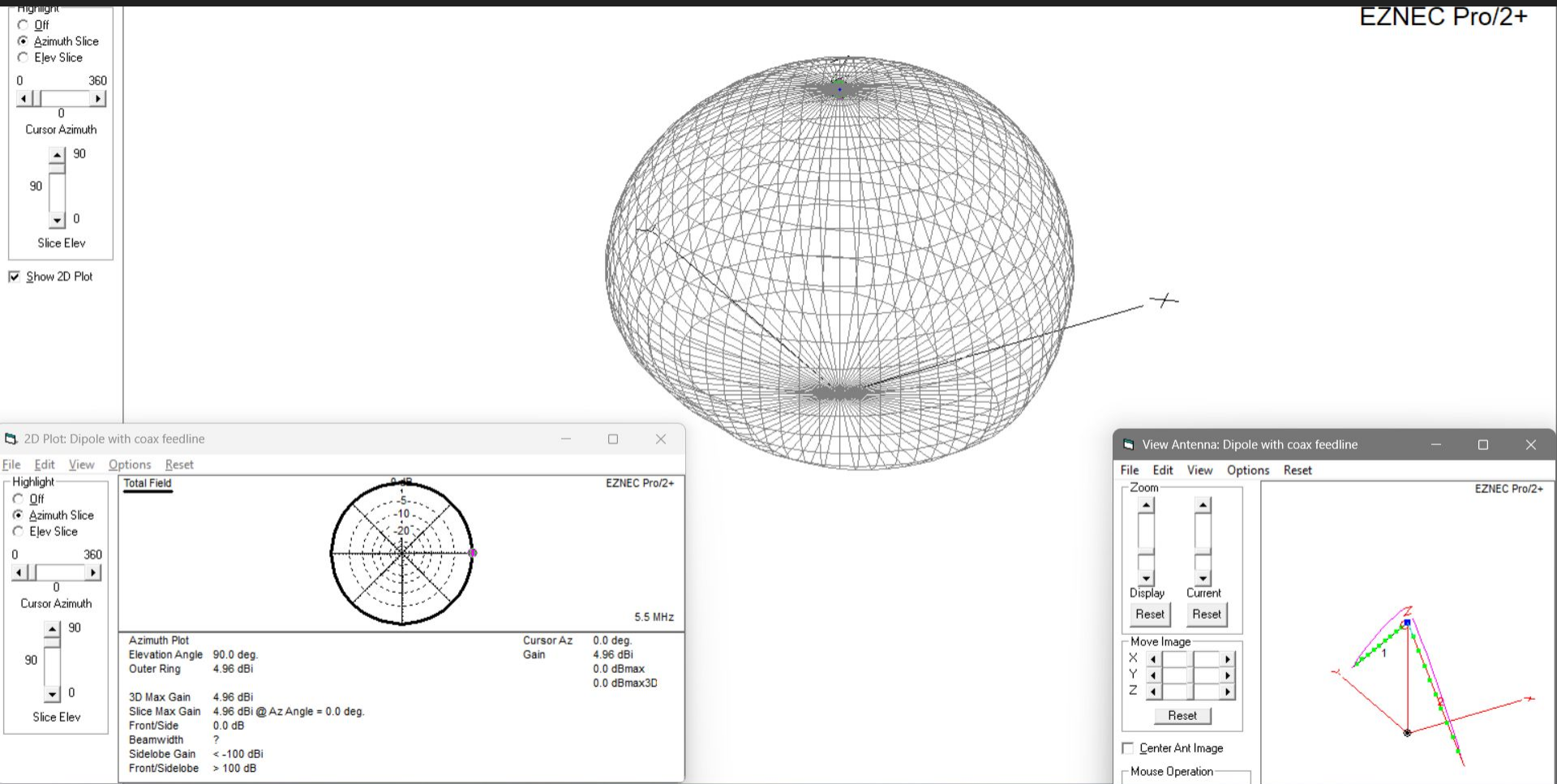




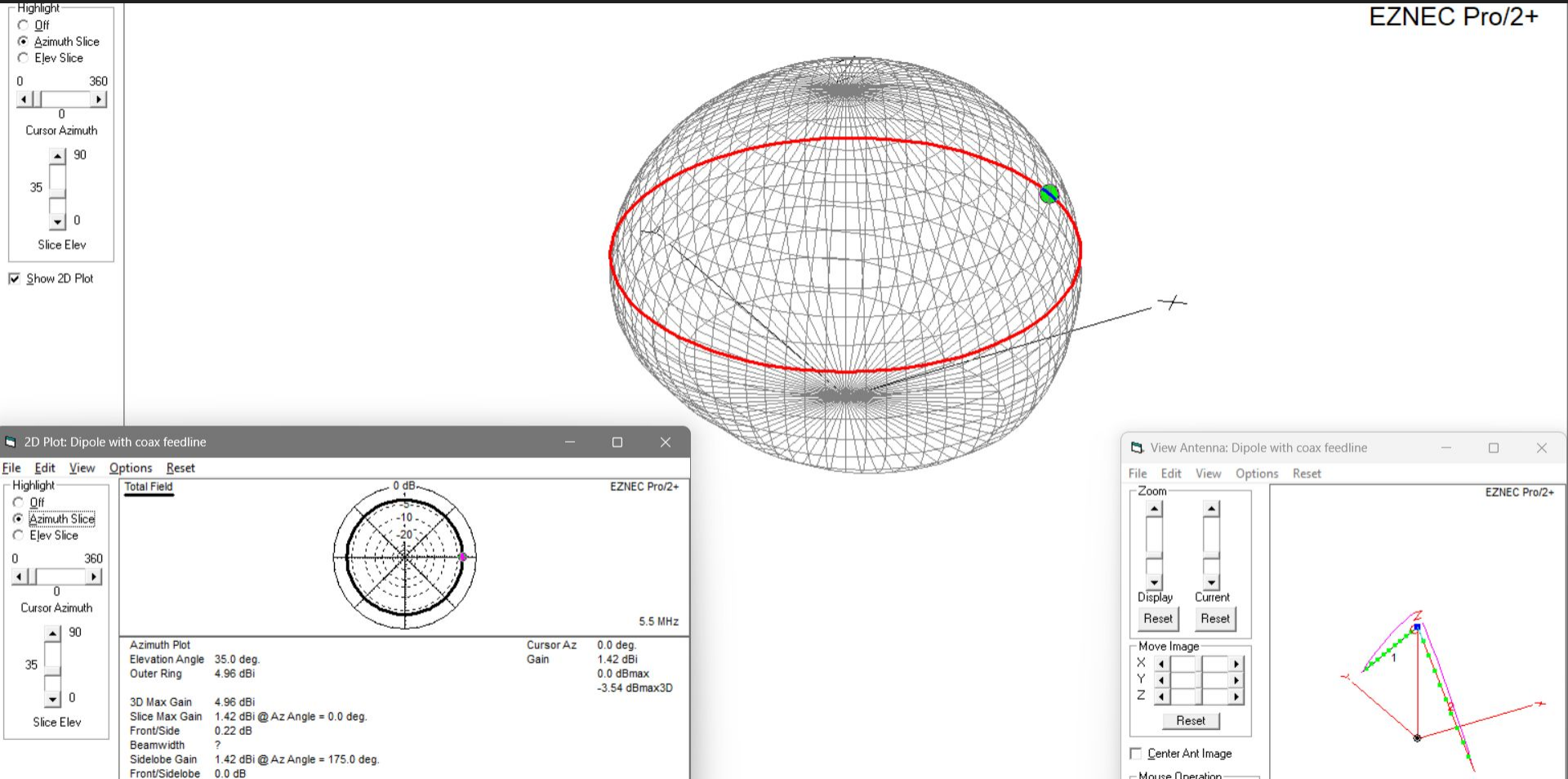
17MHz Elevation Gain (Model)



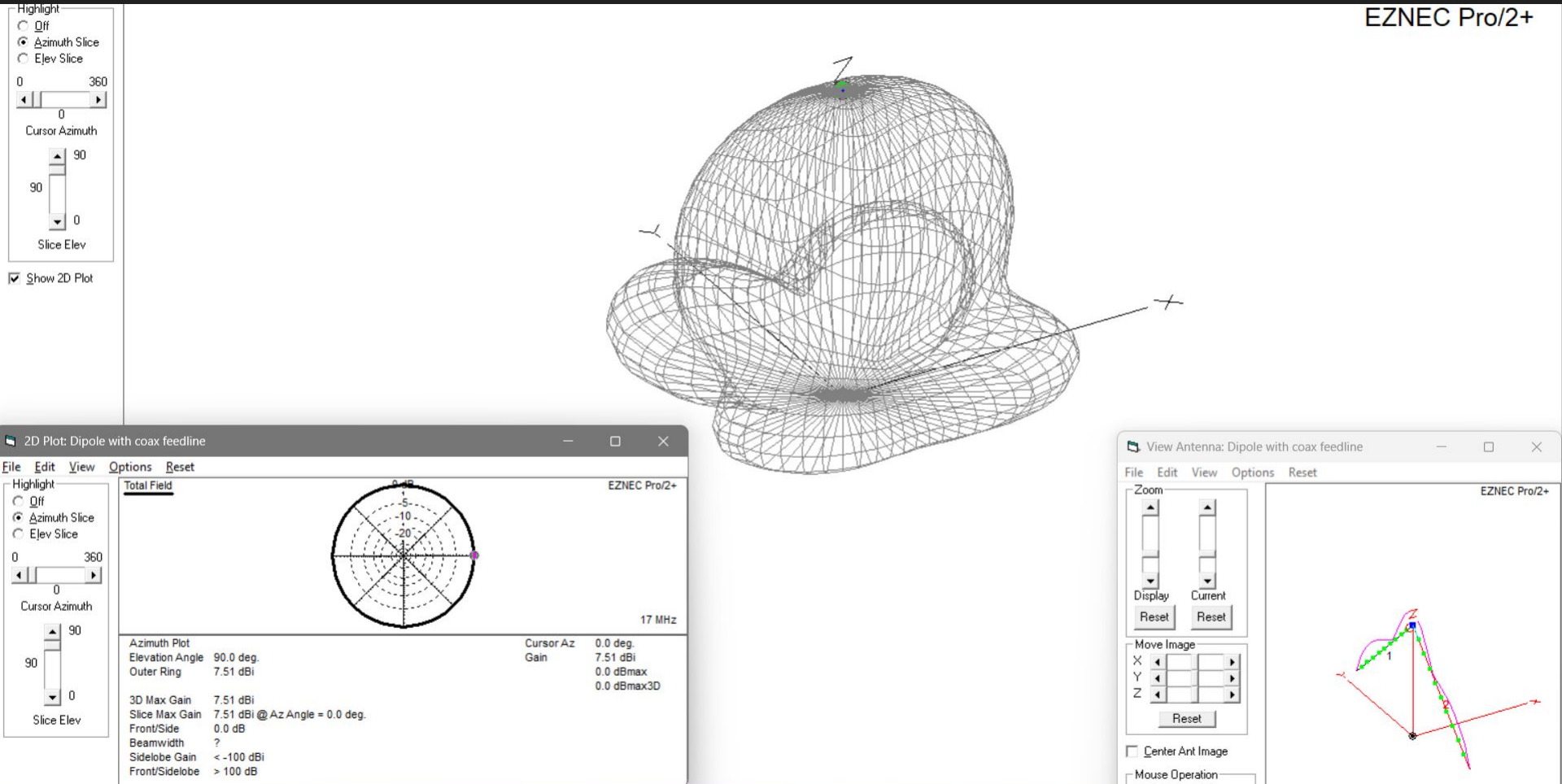
5.5MHz Azimuthal Gain (Model)



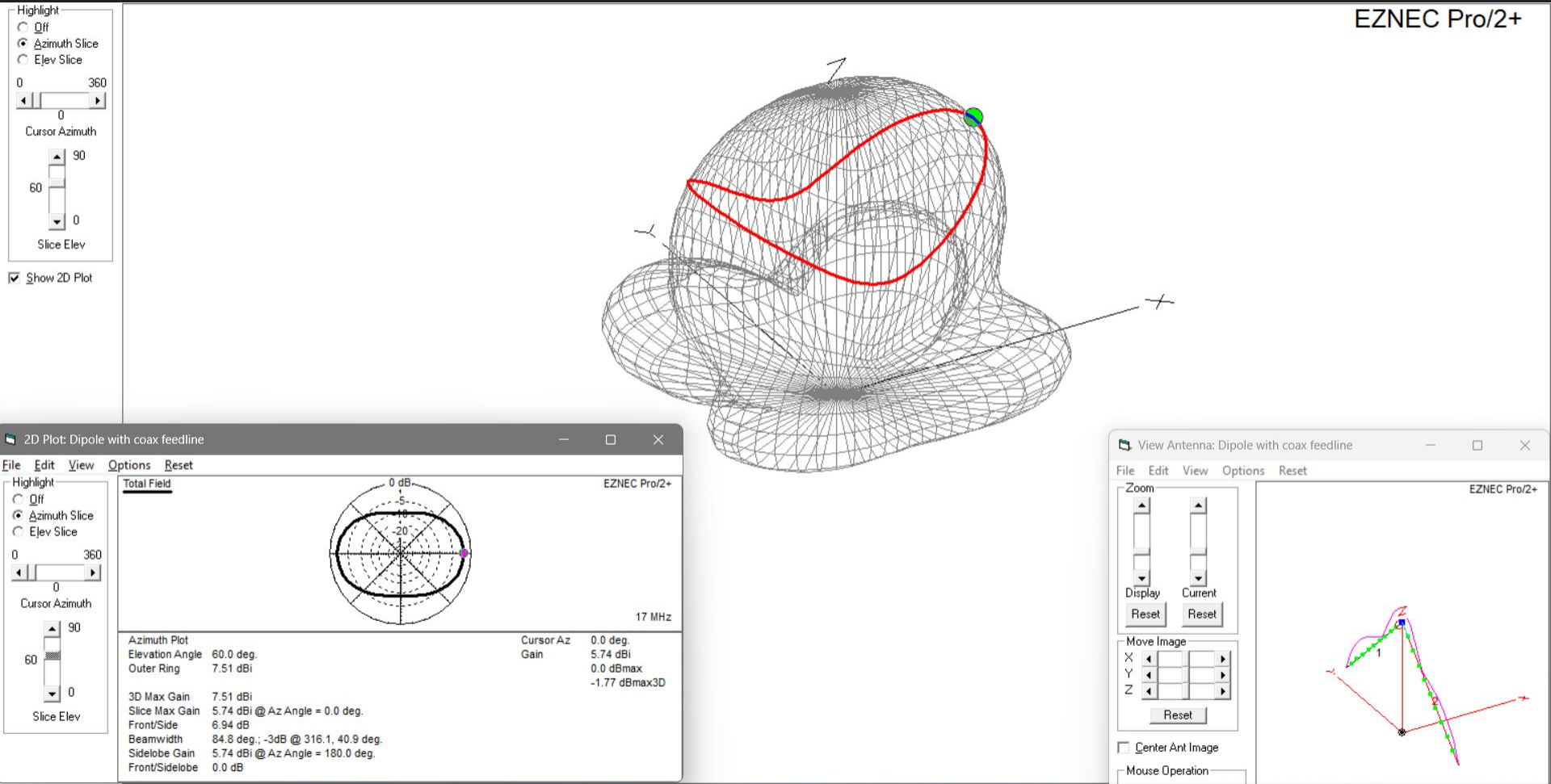
5.5MHz Azimuthal Gain (Model)



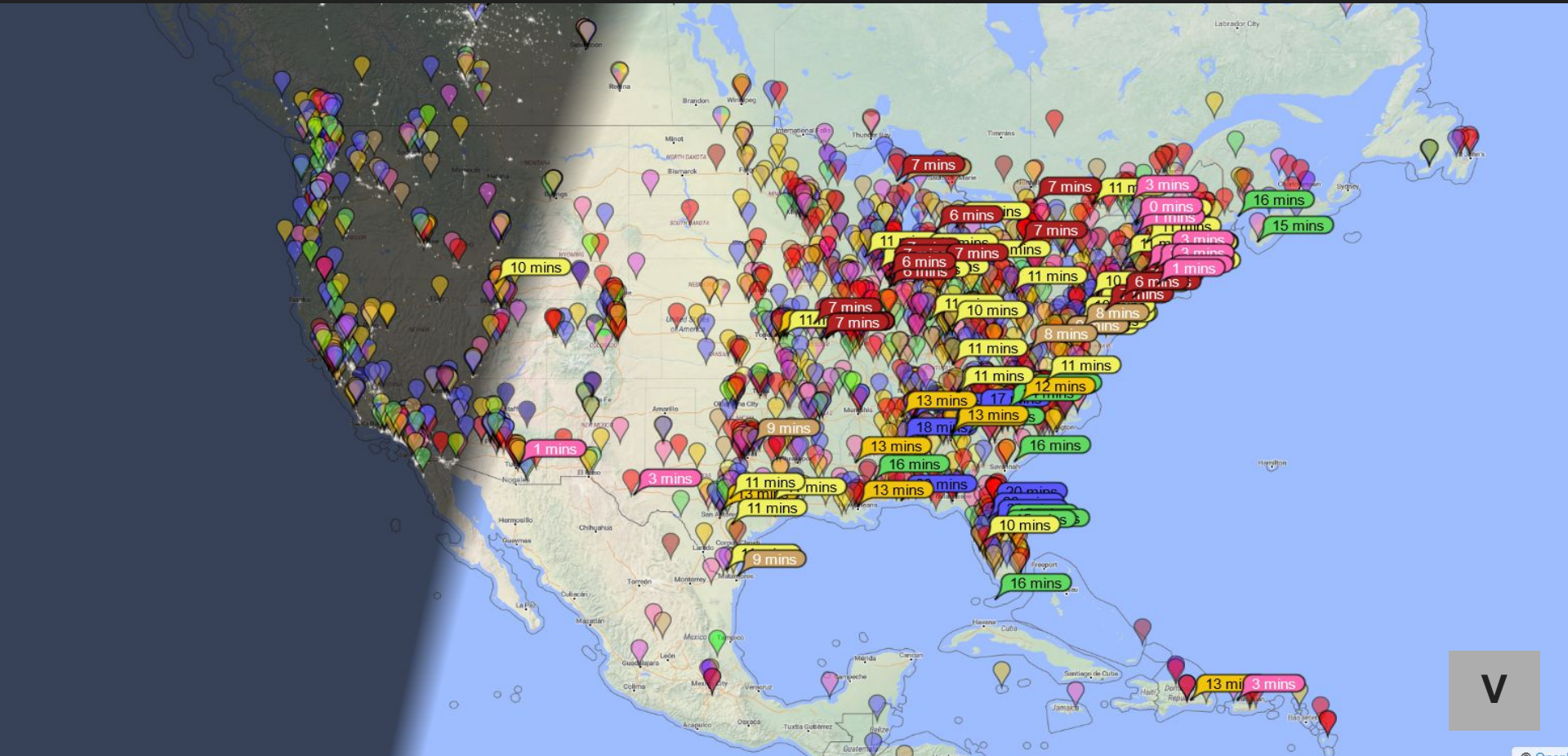
17MHz Azimuthal Gain (Model)



17MHz Azimuthal Gain (Model)



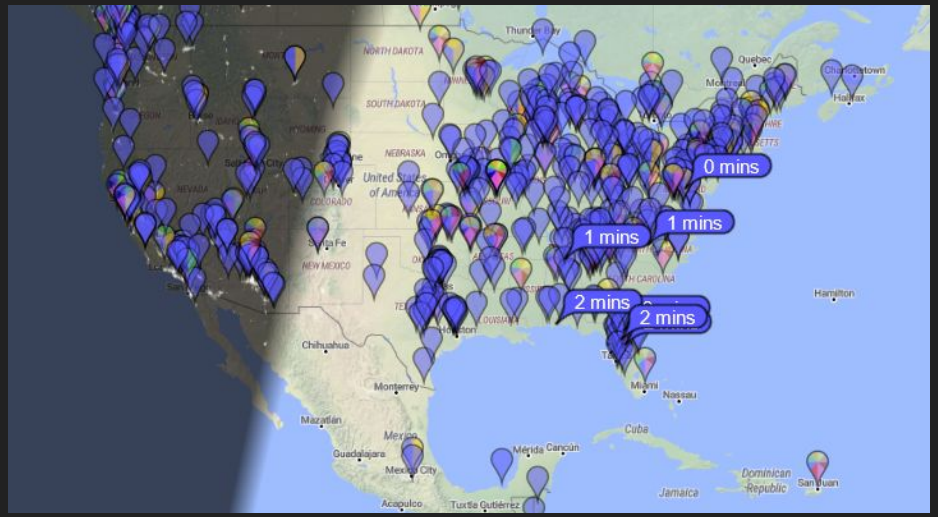
Combined Signal Reports (Measured)
5.5MHz Inverted V // 35’ // 0947L



Signal Reports by Frequency (Measured)

5.5MHz Inverted V // 35’ // 0935L

7 MHz

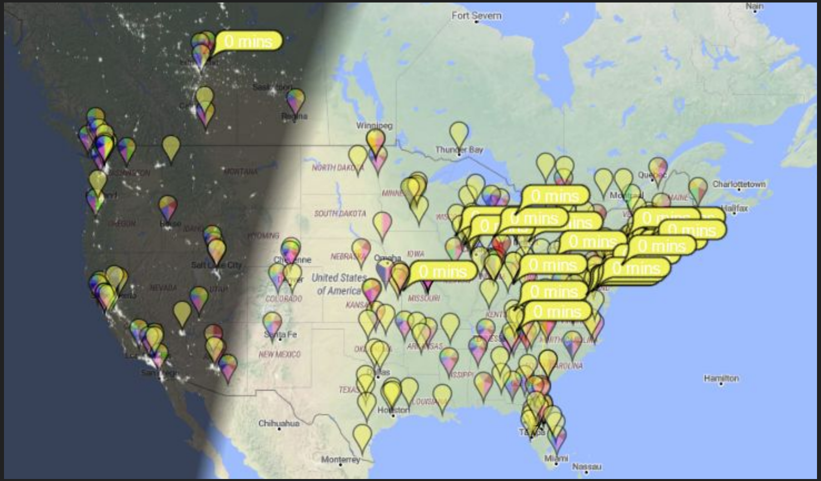


14 MHz

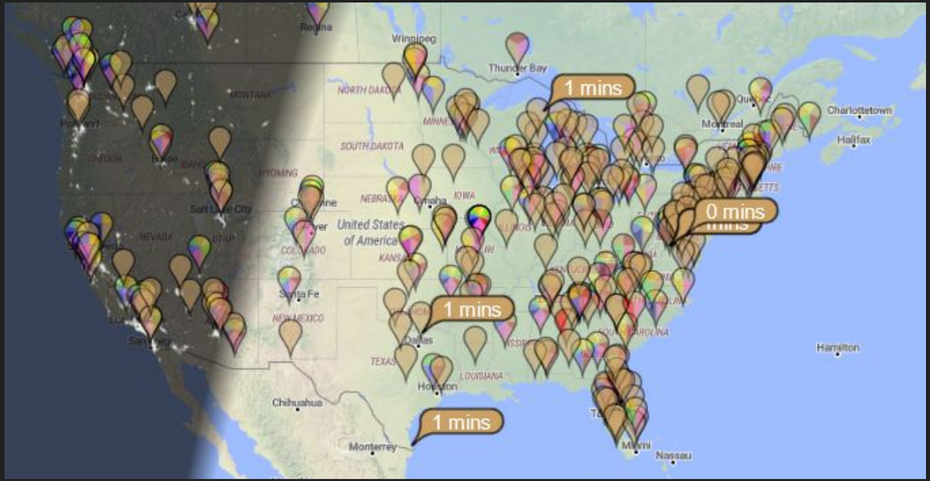
V

Signal Reports by Frequency (Measured)
5.5MHz Inverted V // 35’ // 0948L

18 MHz



21 MHz



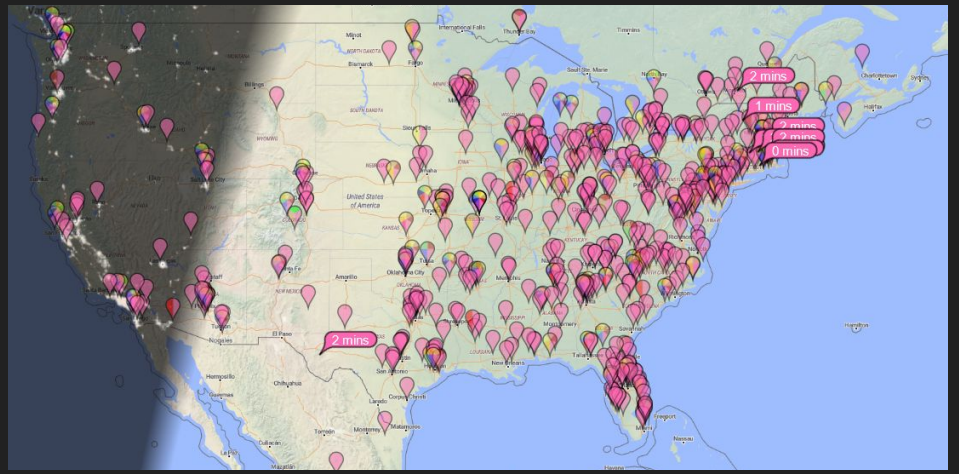
V

Signal Reports by Frequency (Measured)

5.5MHz Inverted V // 35’ // 0947L

24 MHz

28 MHz



V

Key takeaways

- The same antenna will have different patterns depending on the frequency it is used on.
- The shape of a loop somewhat matters. It can be a square, circle, or triangle, but needs to be somewhat symmetrical to have an effective pattern.
- Longer antennas = more harmonics = more spectrum agility and better ALE efficiency

Resources

EZNEC: https://www.eznec.com/

VOACAP Online: https://www.voacap.com/hf/

NanoVNA Saver: https://nanovna.com/?page_id=90

PSKReporter: https://pskreporter.info/pskmap.html

Azimuthal Maps: https://ns6t.net/azimuth/