

# **Yagi antennas:**

**Comparing Height Above Ground  
Real Ground vs. Free Space  
Horizontal vs. Vertical Polarization**

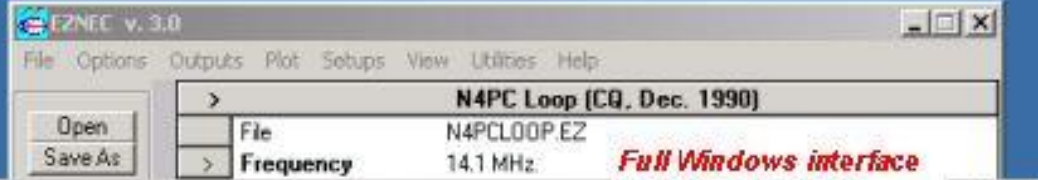
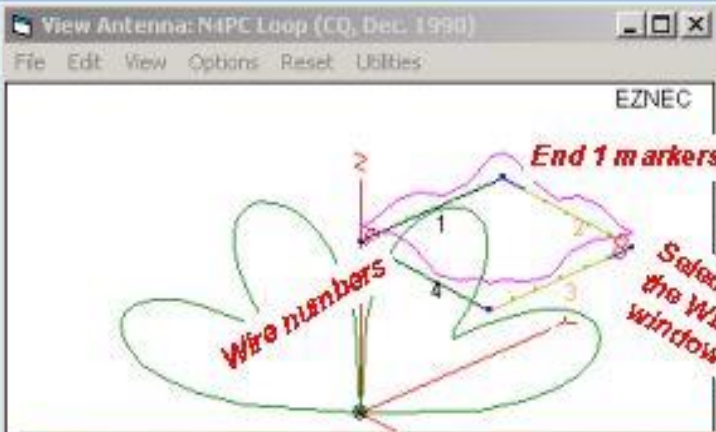
**As plotted with the EZNEC  
Antenna Modeling Program**

Program written by Roy Llewellyn W7EL

**Please note that we are going  
to use a 10 element 2 meter  
Yagi for demonstration purposes**

**But...**

**The elevation takeoff angles  
apply to any horizontal  
antenna at 'x' wavelengths  
above real ground as we will  
see at the end of this presentation.**



Select wires from either the Wires or View Antenna windows

**N4PCLOOP.txt**  
File Edit Search

N4PCLoop

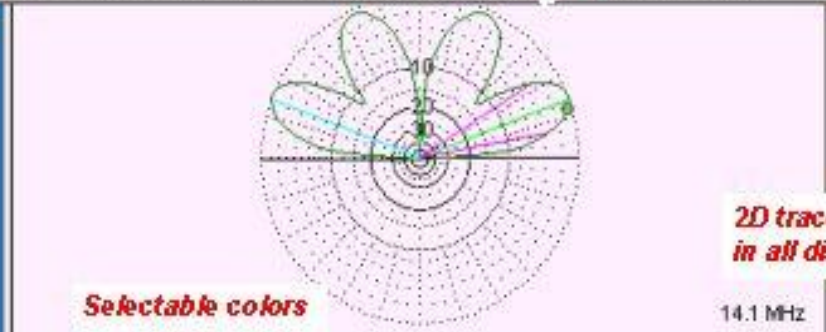
This multiband horizontal loop antenna was created by Paul Carr, N4PC described in December, 1990 CQ Magazine. A unique feature is that opposite corners by out-of-phase signals as in the W8. It has an overhead null on all bands. If you look at the Wires see two sources shown IN phase. This is necessary due to assumed to flow in the wires. When multiple sources are connected

*Antenna Notes Saved with each description*

Wires

	End 2				Diameter	Segs
Conn	X (ft)	Y (ft)	Z (ft)	Conn	(in)	
W4E2	0	51	50	W2E1	#12	6
W1E2	51	51	50	W3E1	#12	6
W2E2	51	0	50	W4E1	#12	6
W3E2	0	0	50	W1E1	#12	6

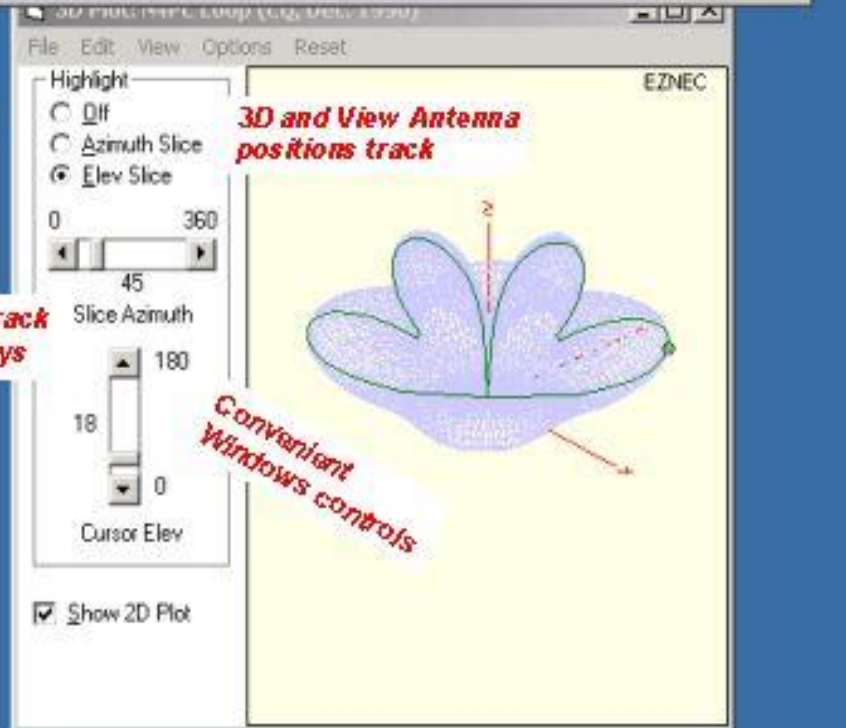
Average Gain = 0.762 = -1.18 dB



Selectable colors

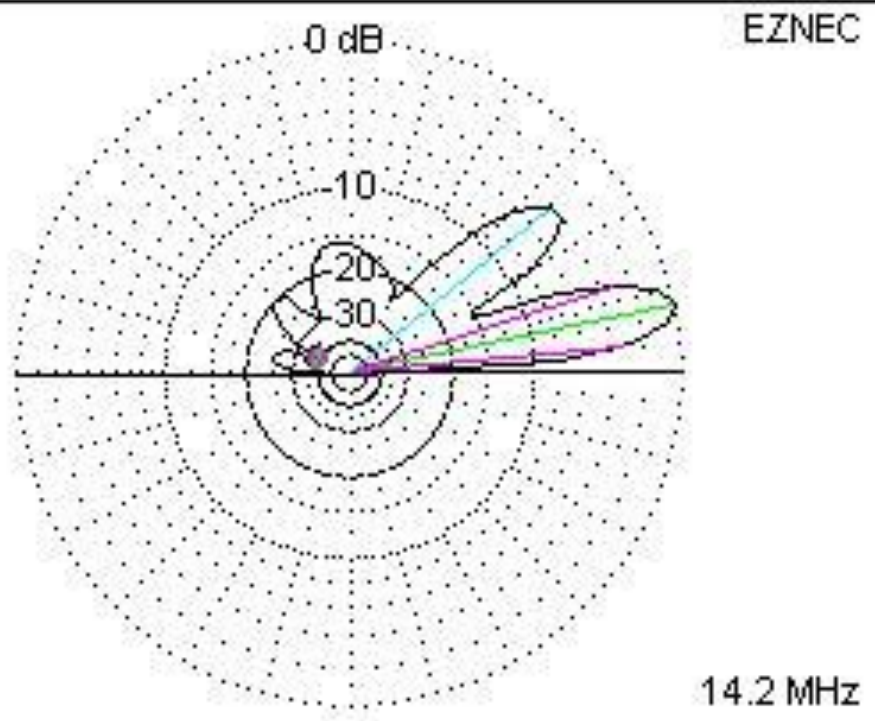
14.1 MHz

Elevation Plot	Cursor Elev	18.0 deg.
Azimuth Angle	Gain	6.75 dBi
Outer Ring		-0.39 dBmax
3D Max Gain		7.14 dBi
Slice Max Gain		7.14 dBi @ Elev Angle = 21.0 deg.
Beamwidth		21.9 deg, -3dB @ 11.3, 33.2 deg.
Sidelobe Gain		7.14 dBi @ Elev Angle = 159.0 deg.
Front/Sidelobe		0.0 dB



# 2D Plot: Five-element Yagi

File Edit View Options Reset



Elevation Plot		Cursor Elev	153.0 deg.
Azimuth Angle	0.0 deg.	Gain	-21.77 dBi
Outer Ring	15.08dBi		-36.86 dBmax
3D Max Gain	15.08 dBi		
Slice Max Gain	15.08 dBi @ Elev Angle = 12.0 deg.		
Beamwidth	12.3 deg.; -3dB @ 5.8, 18.1 deg.		
Sidelobe Gain	10.97 dBi @ Elev Angle = 39.0 deg.		
Front/Sidelobe	4.11 dB		

**EZNEC can plot any antenna  
You can design and tell you  
Where your signal will go.**

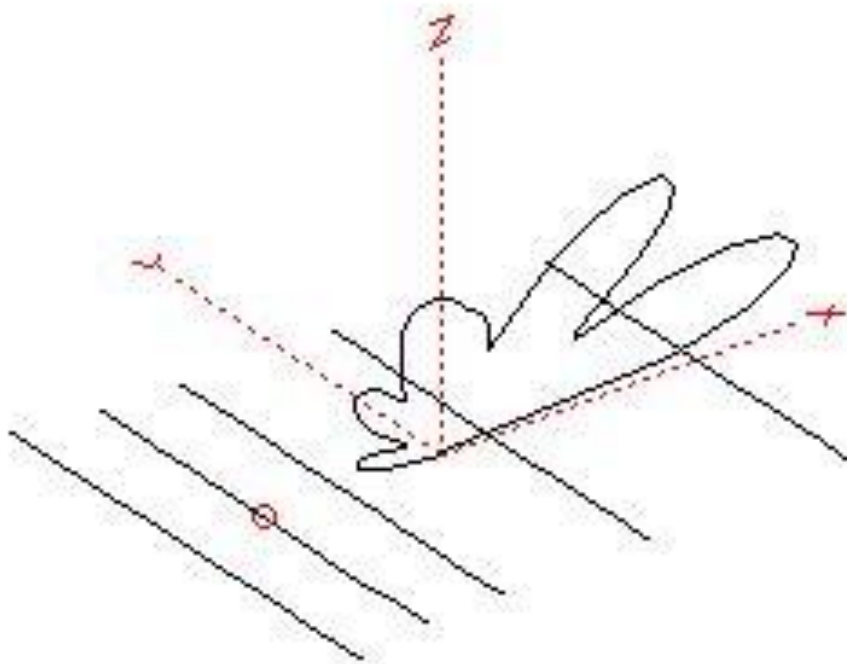
**The program will tell you  
What you are plotting and  
info on gain, beam width,  
takeoff angles and more...**

# View Antenna: Five-element Yagi



File Edit View Options Reset

EZNEC



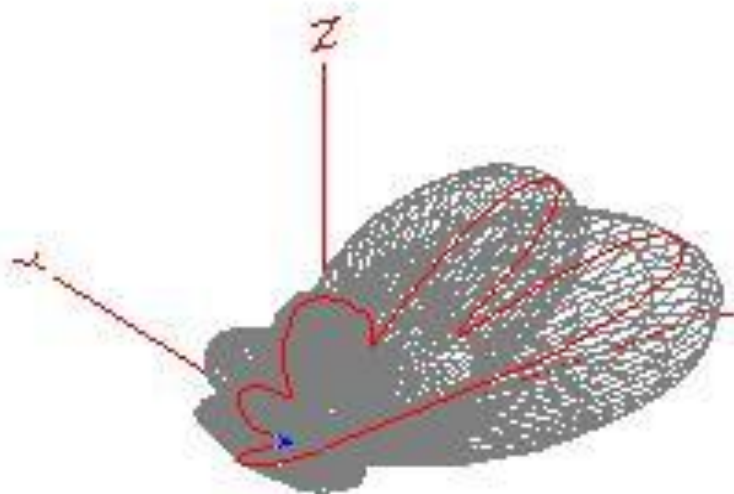
**For any given height above ground it will show you the entire radiation pattern.**

# 3D Plot: Five-element Yagi

File Edit View Options Reset



EZNEC



**It can show you a  
Plot in 3-D as well.**

Name	Date modified	Type	Size
1.8 MHz	d_20m5EIYa		
7 MHz	d_DipTL		
10 MHz	d_Elevrad1		
28 MHz	d_ElevRad2		
50 MHz	d_FDSP		
144 MHz	d_K5RP		
432 MHz	d_Last		
Other	d_LogPer		
4sqtl	d_LogPerTL		
4Square L Network Feed ARRL Example	d_N4PCLoop		
4Square L Network Feed With Z Matching	d_NBSYagi		
4Square TL ARRL Example	d_VHFGP		
4square	d_W8JK		
15mquad	Dipole1		
20m5elya	Diptl		
BYDipole	Elevrad1		
BYVee	Elevrad2		
Cardioid L Network Feed ARRL Example	Fdsp		
Cardioid TL ARRL Example	K5rp		
Cardioid	LAST		
CardTL	Logper		
d_4SqTL	Logpertl		
d_4square	N4pcloop		
d_15mQuad	Nbsyagi		

**There are many files available on the internet and in the program, itself, so you do not have to start from scratch to build an antenna**

**Let's start with a 10 element 2 meter Yagi**



File Edit Options Outputs Setups View Utilities Help

- Open
- Save As
- Ant Notes
- Currents
- Src Dat
- Load Dat
- FF Tab
- NF Tab
- SWR
- View Ant
- FF Plot

> YU7EF EF0210LT 144 MHz		
	File	LAST.EZ
>	<b>Frequency</b>	144.2 MHz
	Wavelength	2079.01 mm
>	<b>Wires</b>	10 Wires, 270 segments
>	<b>Sources</b>	1 Source
>	<b>Loads</b>	0 Loads
>	<b>Trans Lines</b>	0 Transmission Lines
>	<b>Transformers</b>	0 Transformers
>	<b>L Networks</b>	0 L Networks
>	<b>Ground Type</b>	Free Space
>	<b>Wire Loss</b>	Zero
>	<b>Units</b>	Millimeters
>	<b>Plot Type</b>	3D
>	<b>Step Size</b>	5 Deg.
>	<b>Ref Level</b>	0 dBi
>	<b>Alt SWR Z0</b>	75 ohms
>	<b>Desc Options</b>	

# EZNEC MAIN SCREEN

Wires

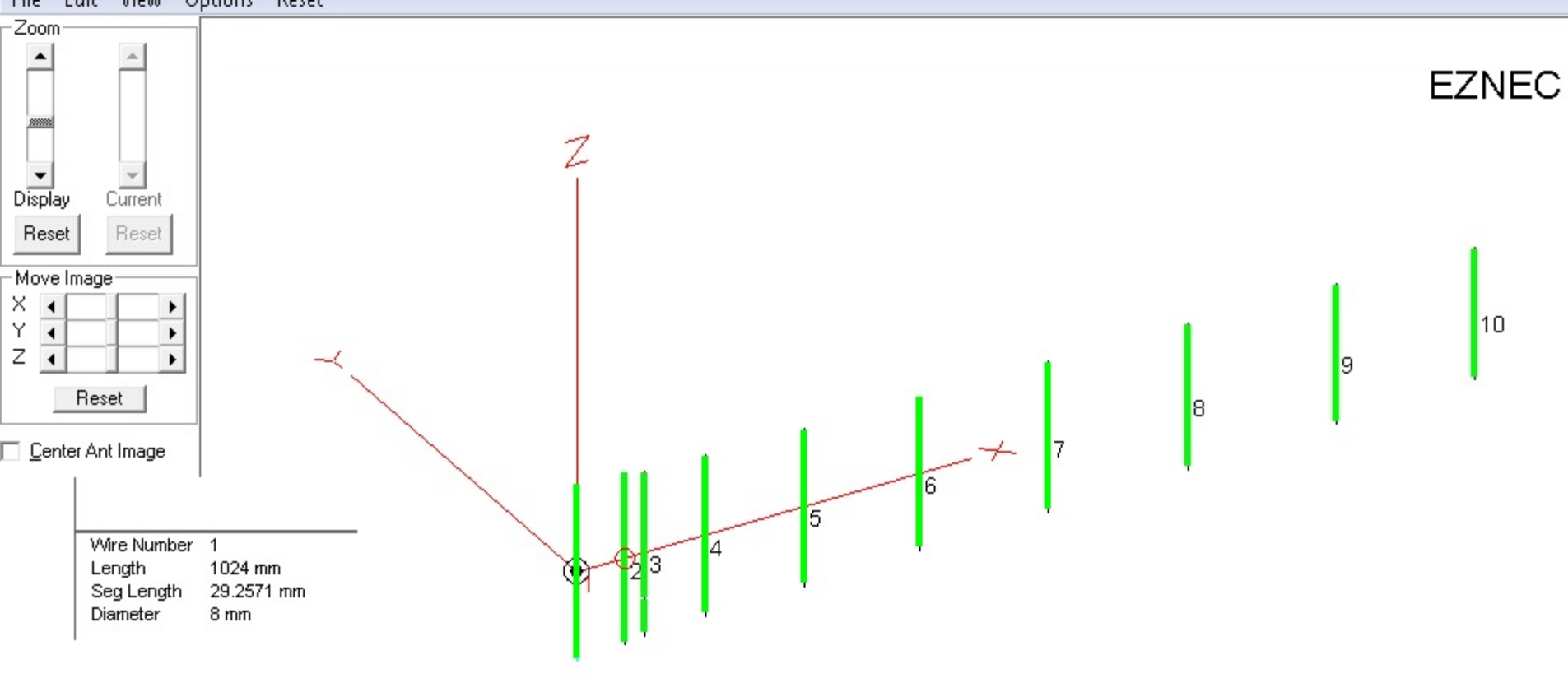
Wire Create Edit Other

Coord Entry Mode     Preserve Connections     Show Wire Insulation

Wires

No.	End 1				End 2				Diameter (mm)	Segs	Insulation	
	X (mm)	Y (mm)	Z (mm)	Conn	X (mm)	Y (mm)	Z (mm)	Conn			Diel C	Thk (mm)
▶ 1	0	0	-512		0	0	512		8	35	1	0
2	280	0	-502		280	0	502		8	35	1	0
3	387	0	-480.5		387	0	480.5		8	25	1	0
4	744	0	-472.5		744	0	472.5		8	25	1	0
5	1318	0	-461.5		1318	0	461.5		8	25	1	0
6	1984	0	-450.5		1984	0	450.5		8	25	1	0
7	2727	0	-439.5		2727	0	439.5		8	25	1	0
8	3536	0	-428.5		3536	0	428.5		8	25	1	0
9	4390	0	-409.5		4390	0	409.5		8	25	1	0
10	5190	0	-385		5190	0	385		8	25	1	0
*												

**The wires screen allows you to position each wire  
Or piece of tubing in the X-Y-Z dimensions and  
Designate its length, position and diameter.**



**Then you can show the antenna and flip and Rotate it in all 3 planes to look at it.**

Zoom

Display Current

Reset Reset

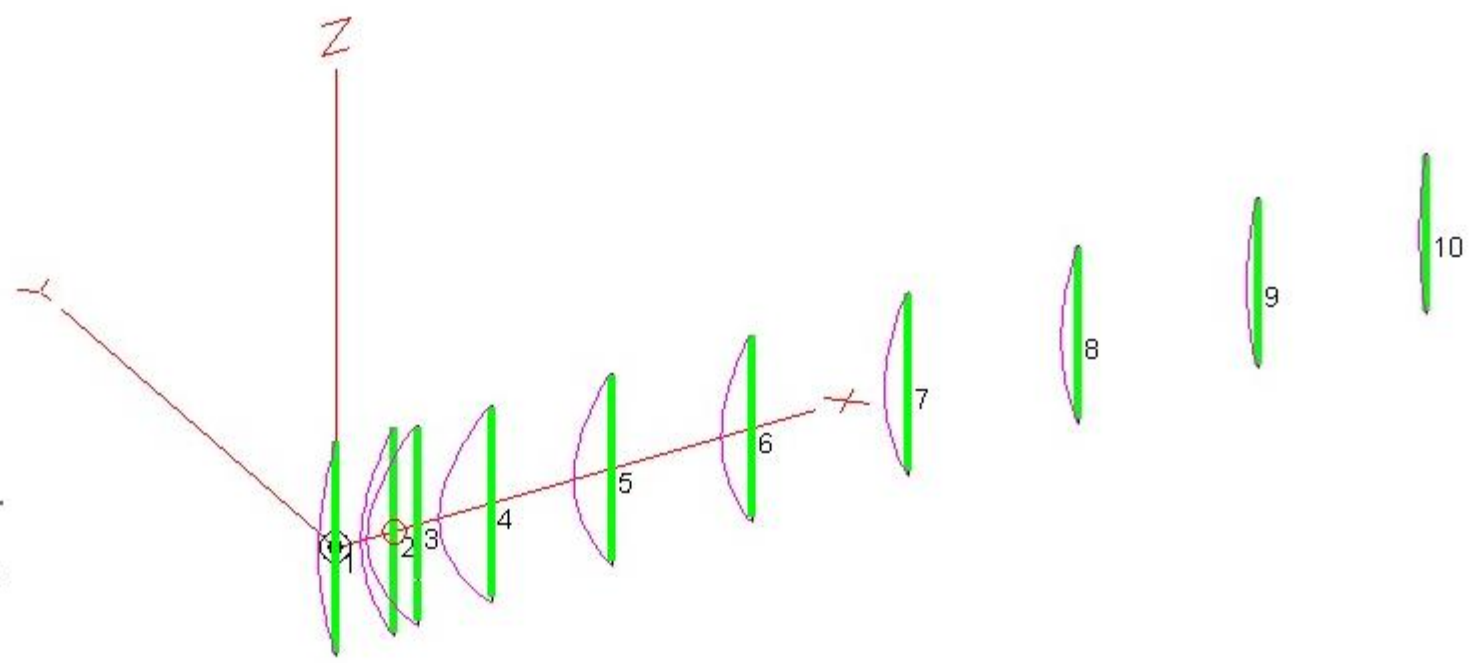
Move Image

X	←	→
Y	←	→
Z	←	→

Reset

Center Ant Image

Wire Number	1
Length	1024 mm
Seg Length	29.2571 mm
Diameter	8 mm



EZNEC

**And it can display the Currents on Each element of the antenna**

# Other views of the 10 element yagi

Zoom

Display Current

Reset Reset

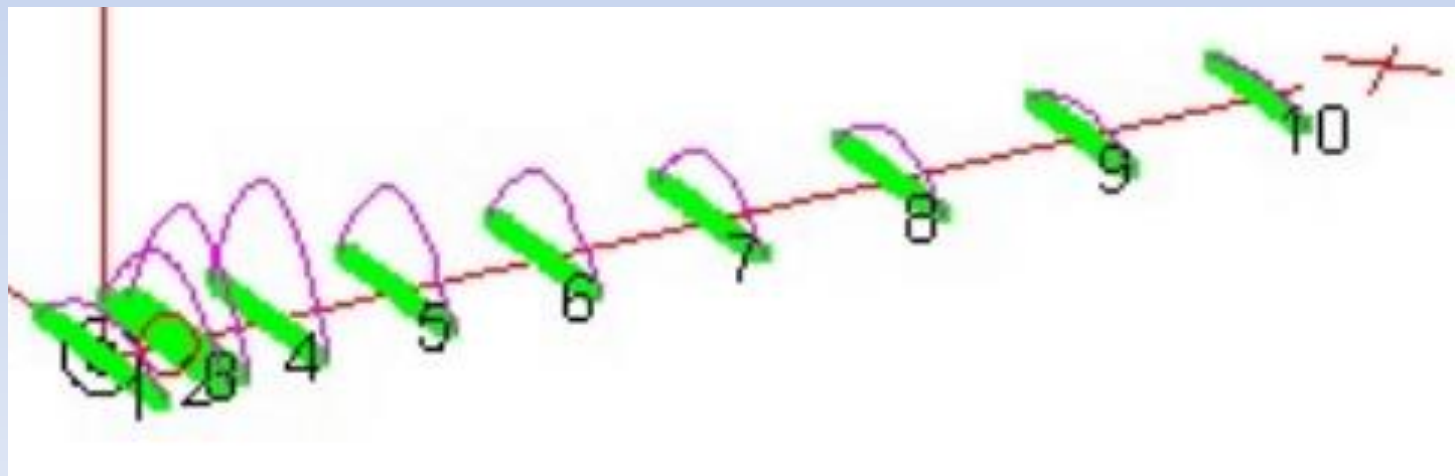
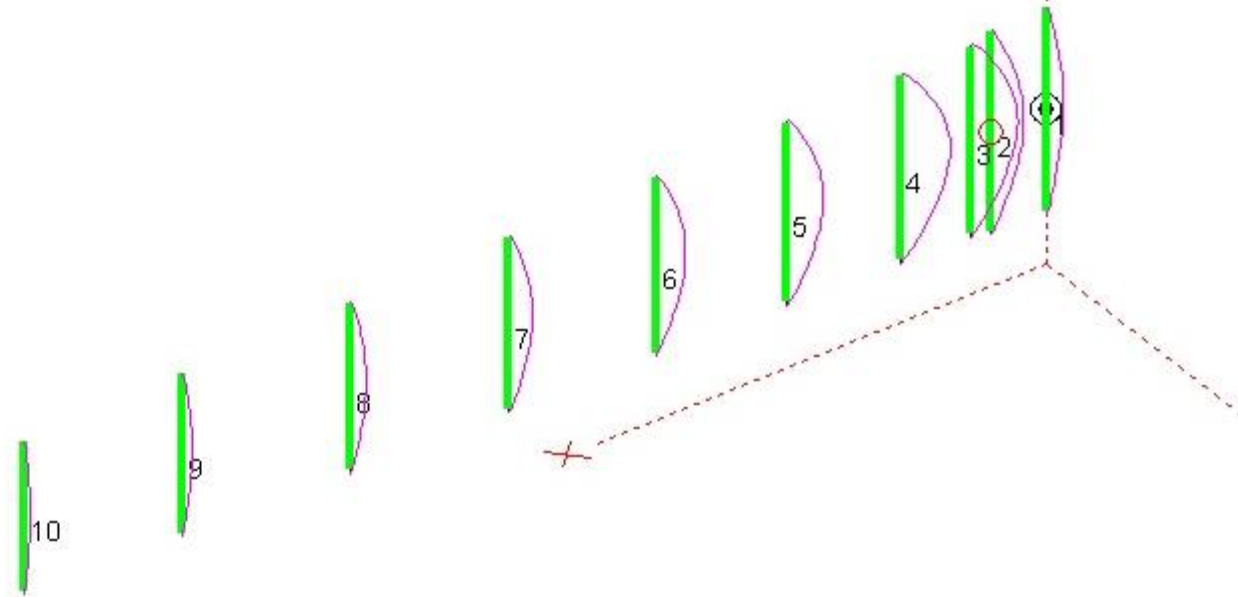
Move Image

X Y Z

Reset

Center Ant Image

Wire Number 1  
Length 1024 mm  
Seg Length 29.2571 mm  
Diameter 8 mm



- Add...
- Delete...
- Move Wire(s) in List...
- Group Modify...
- Auto Seg ▶
- Change Height by...
- Change Loop Size...
- Copy Wires...
- Move Wires XYZ...
- Rotate Wires...
- Scale Wires...
- Stack...
- Taper Segs...
- Reset Tapered Color

Connections  Show Wire Insulation

Wires				
		End 2		
(mm)	Conn	X (mm)	Y (mm)	Z (mm)
2		0	0	512
2		280	0	502
0.5		387	0	480.5
2.5		744	0	472.5
0.5		1318	0	461.5
0.5		1984	0	450.5
0.5		2727	0	439.5
0.5		3536	0	428.5
0.5		4390	0	409.5
5		5190	0	385

0 deg.  
0 dBi  
75 ohms

**You can change many parameters of the antenna**

**EZNEC will allow you to plot SWR curves and Smith charts for your antenna.**

**It can help you design matching sections, L networks and transformers.**

**It can examine transmission lines you may want to use with an antenna.**

**You can choose the type of ground your antenna is over.**

It will **check** that you have not made any **errors** in the wire symmetry that you have specified.

It allows you to write and save notes on any antenna you have designed.

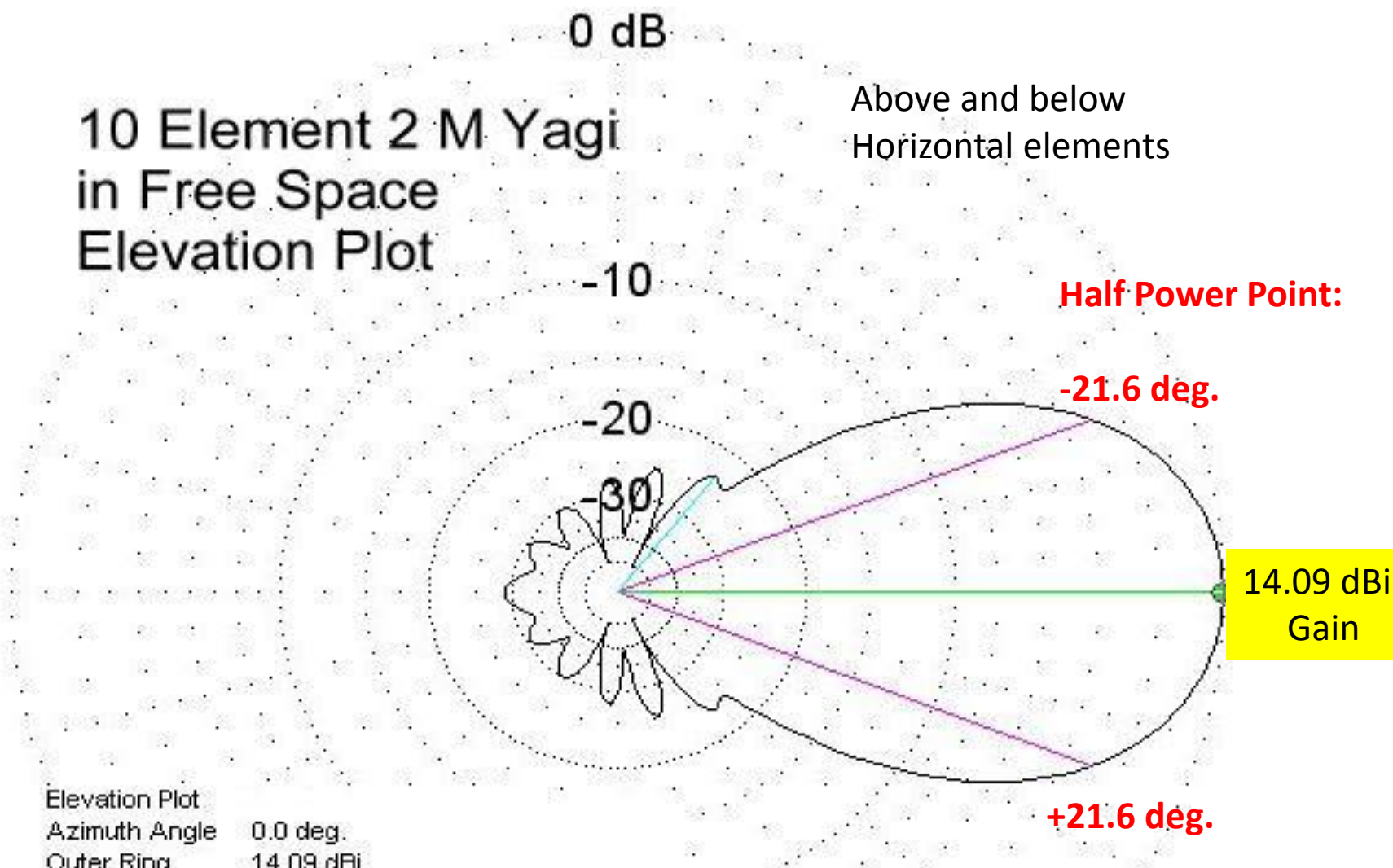
**Lets look at a horizontal 10 element 2M Yagi  
elevation and azimuth patterns in FREE SPACE.**

**This means the antenna is nowhere near  
any ground or structures which could  
affect the pattern of the antenna.**

(Ideally, out in Space)

# 10 Element 2 M Yagi in Free Space Elevation Plot

Above and below  
Horizontal elements



**Half Power Point:**

**-21.6 deg.**

**14.09 dBi  
Gain**

**+21.6 deg.**

Elevation Plot  
Azimuth Angle 0.0 deg.  
Outer Ring 14.09 dBi

→ Slice Max Gain 14.09 dBi @ Elev Angle = 0.0 deg.  
Front/Back 28.83 dB  
Beamwidth 43.2 deg.; -3dB @ 338.4, 21.6 deg.  
Sidelobe Gain -8.87 dBi @ Elev Angle = 52.0 deg.  
Front/Sidelobe 22.96 dB

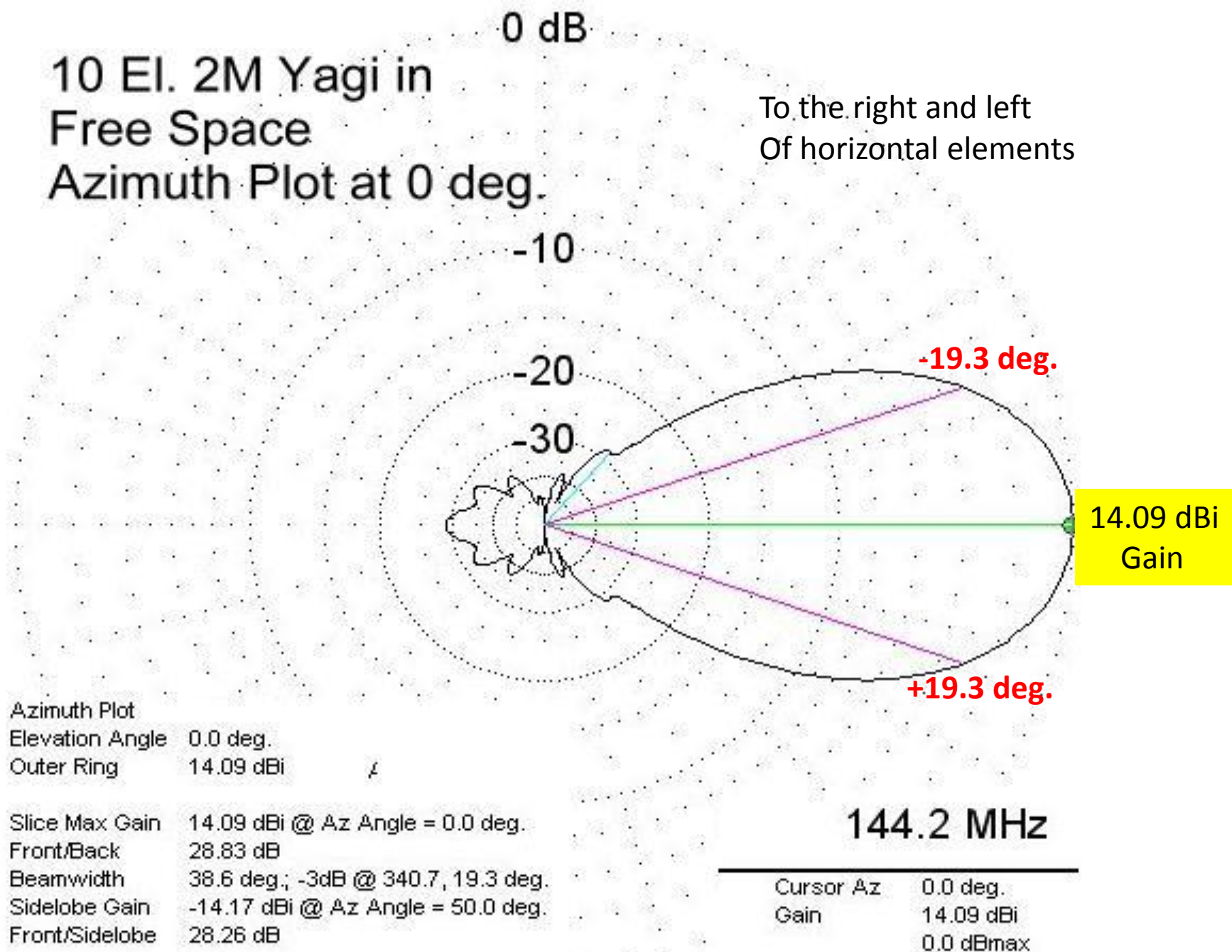
**144.2 MHz**

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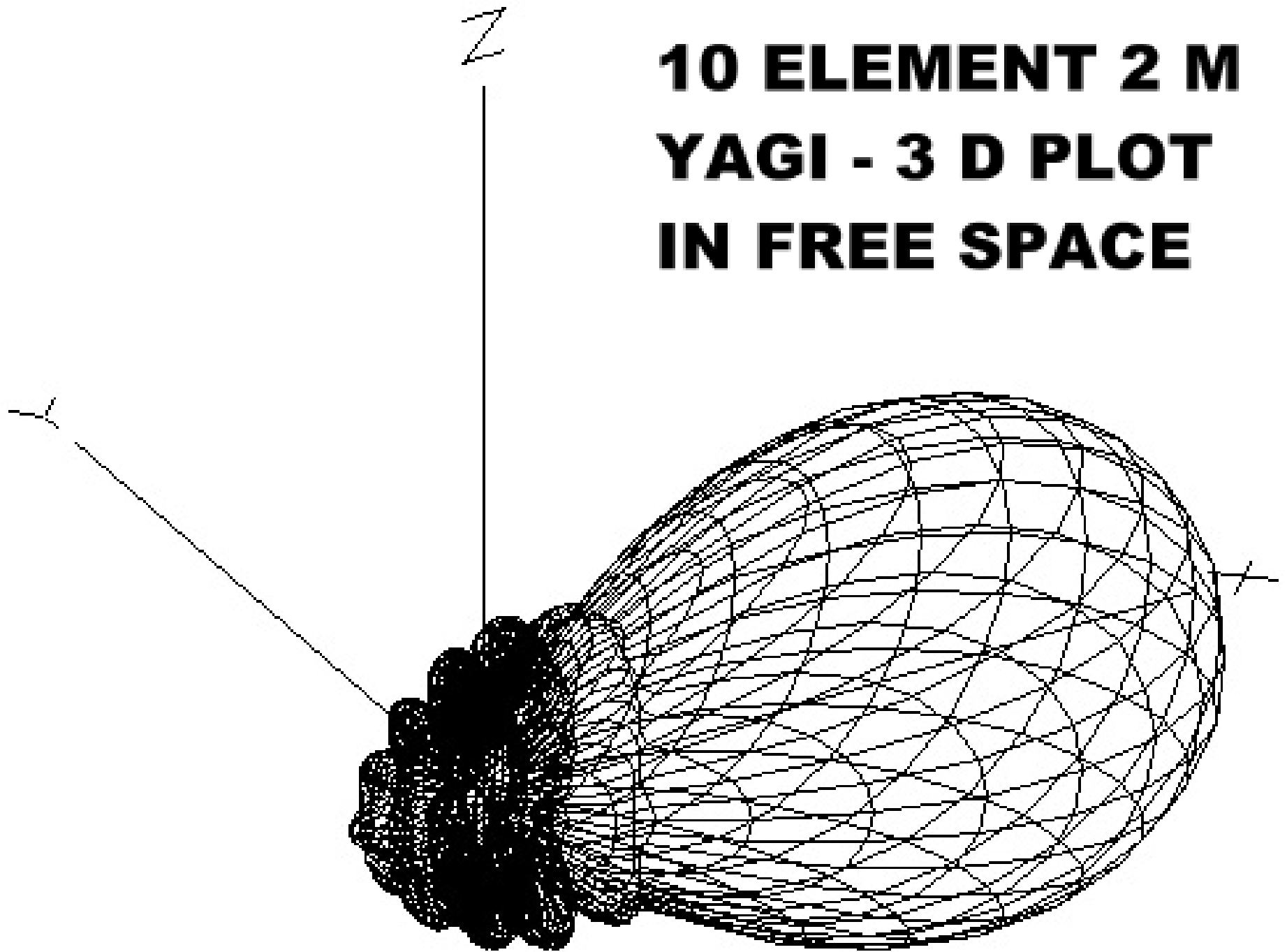
Cursor Elev 0.0 deg.  
Gain 14.09 dBi  
0.0 dBmax

# 10 El. 2M Yagi in Free Space Azimuth Plot at 0 deg.

To the right and left  
Of horizontal elements



**10 ELEMENT 2 M  
YAGI - 3 D PLOT  
IN FREE SPACE**



**Next we put the antenna  $1/4$  wavelength  
above real ground**

**Note that the bottom half of the pattern  
is affected by the ground as is reflected in the  
lobes created at various takeoff angles**

**Also note the major lobe takeoff angle.**

**Follow the takeoff angle and number of  
lobes as the antenna is placed higher.**

# 10 El 2 M Yagi H. Pol up 1/4 Wavelength.

½ Meter (~19")  
Above Ground

144.2 MHz

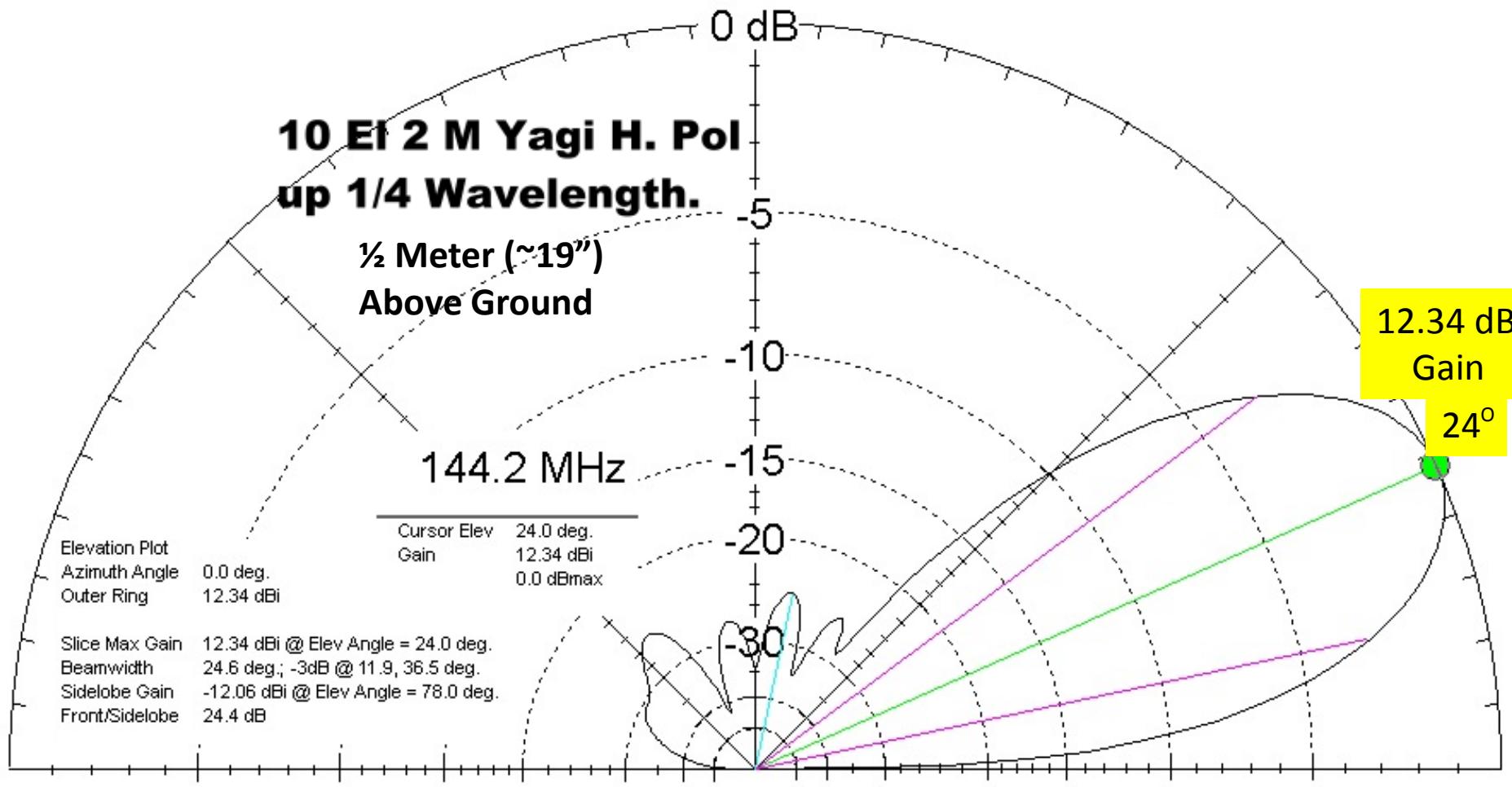
Elevation Plot  
Azimuth Angle 0.0 deg.  
Outer Ring 12.34 dBi

Cursor Elev 24.0 deg.  
Gain 12.34 dBi  
0.0 dBmax

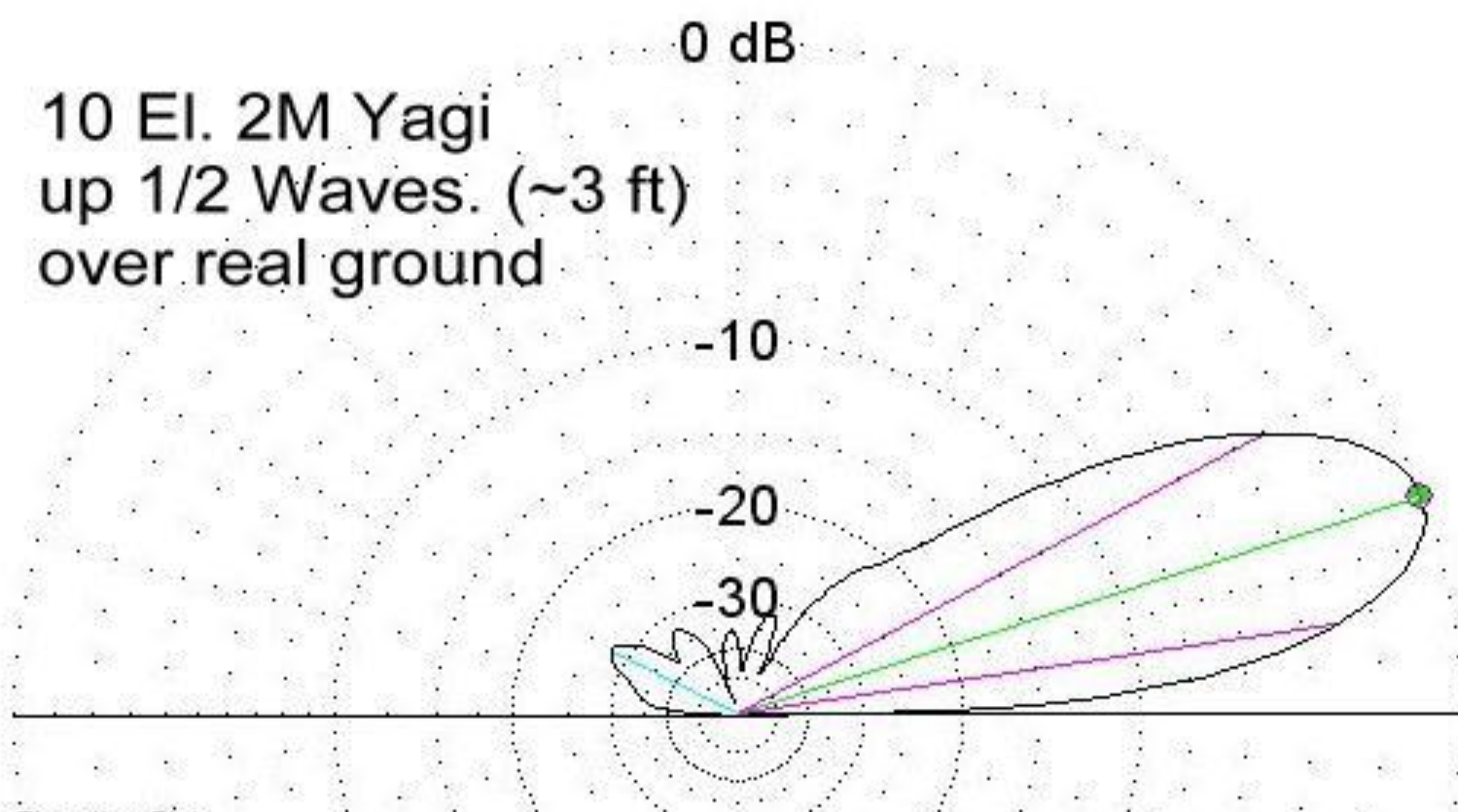
Slice Max Gain 12.34 dBi @ Elev Angle = 24.0 deg.  
Beamwidth 24.6 deg.; -3dB @ 11.9, 36.5 deg.  
Sidelobe Gain -12.06 dBi @ Elev Angle = 78.0 deg.  
Front/Sidelobe 24.4 dB

12.34 dBi  
Gain

24°



10 El. 2M Yagi  
up 1/2 Waves. (~3 ft)  
over real ground



19 Deg.  
15.74 dBi  
Gain

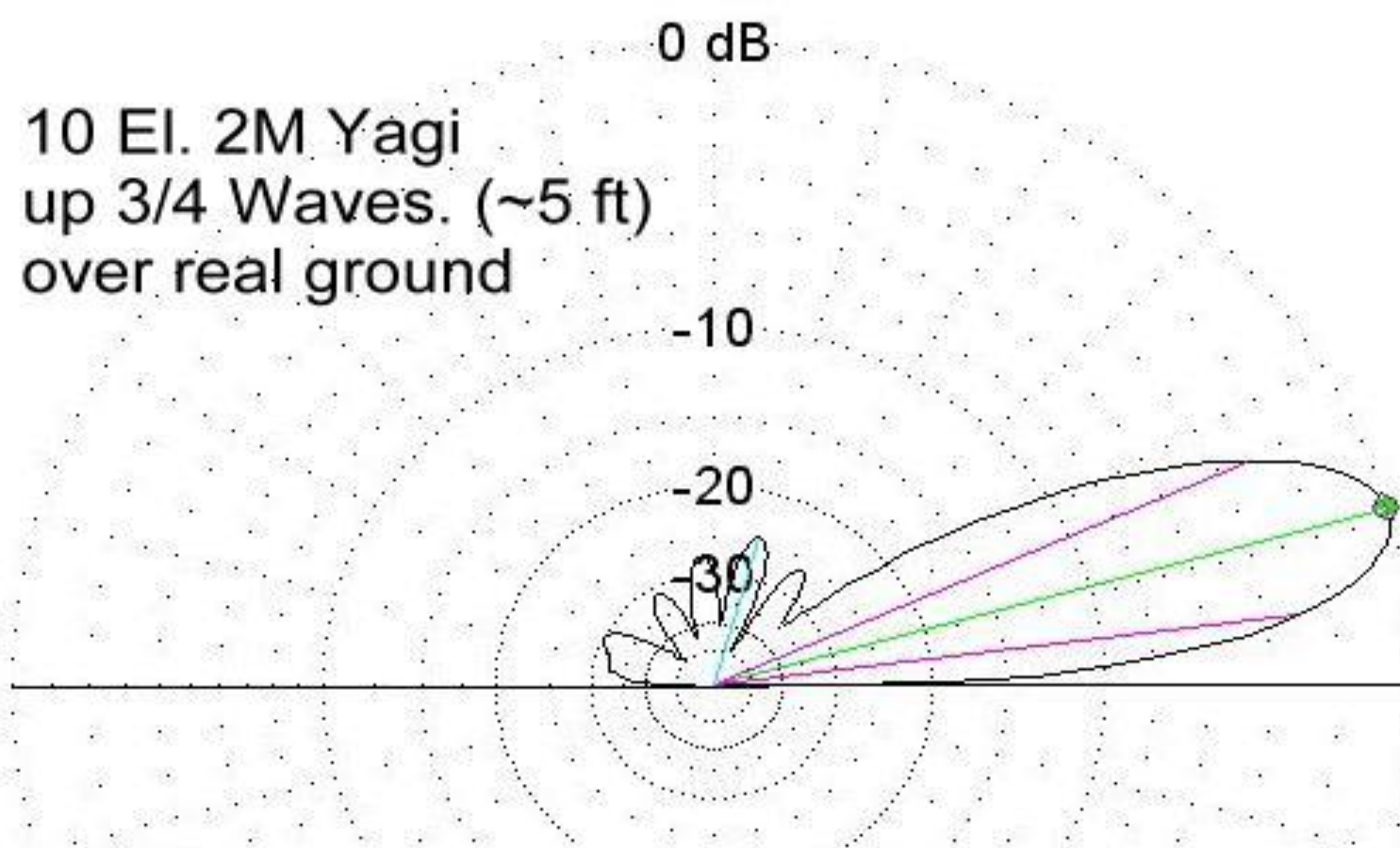
Elevation Plot  
Azimuth Angle 0.0 deg.  
Outer Ring 15.74 dBi

Slice Max Gain 15.74 dBi @ Elev Angle = 19.0 deg.  
Beamwidth 20.6 deg.; -3dB @ 9.3, 29.9 deg.  
Sidelobe Gain -12.04 dBi @ Elev Angle = 151.0 deg.  
Front/Sidelobe 27.78 dB

144.2 MHz

Cursor Elev 19.0 deg.  
Gain 15.74 dBi  
0.0 dBmax

10 El. 2M Yagi  
up 3/4 Waves. (~5 ft)  
over real ground



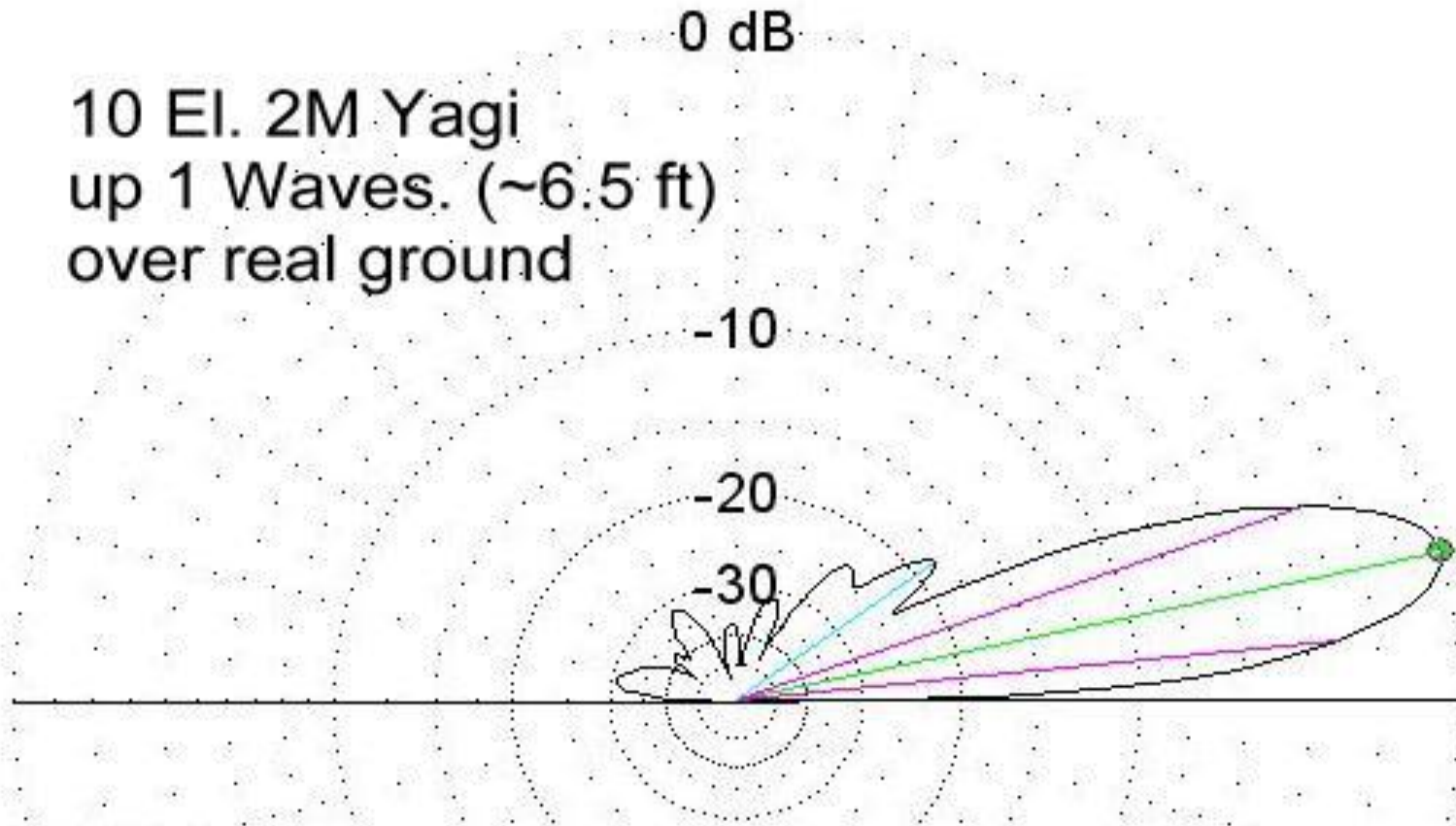
Elevation Plot  
Azimuth Angle 0.0 deg.  
Outer Ring 17.52 dBi

Slice Max Gain 17.52 dBi @ Elev Angle = 16.0 deg.  
Beamwidth 17.1 deg.; -3dB @ 7.6, 24.7 deg.  
Sidelobe Gain -6.92 dBi @ Elev Angle = 74.0 deg.  
Front/Sidelobe 24.44 dB

144.2 MHz

Cursor Elev 16.0 deg.  
Gain 17.52 dBi  
0.0 dBmax

10 El. 2M Yagi  
up 1 Waves. (~6.5 ft)  
over real ground



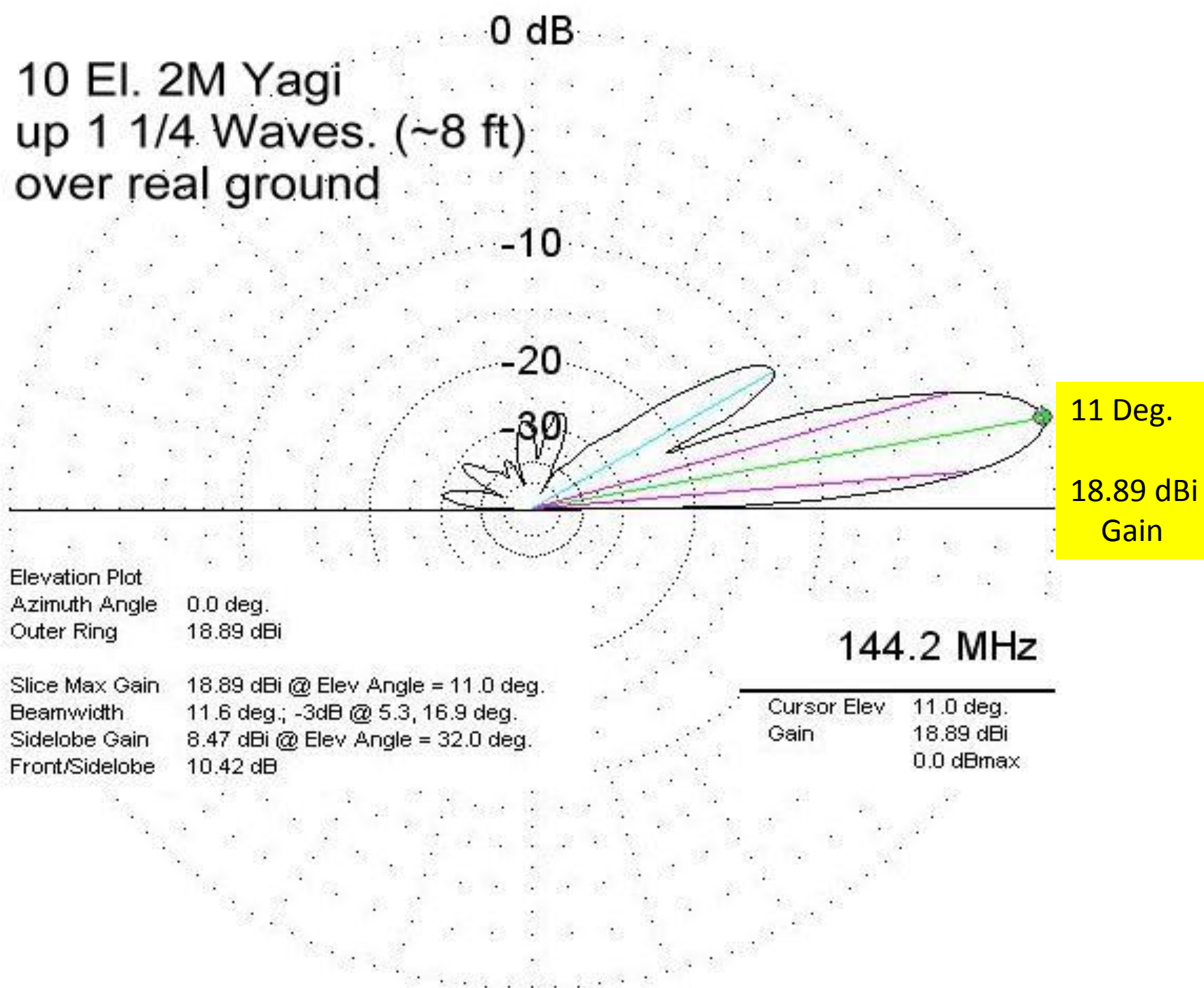
Elevation Plot  
Azimuth Angle 0.0 deg.  
Outer Ring 18.36 dBi

Slice Max Gain 18.36 dBi @ Elev Angle = 13.0 deg.  
Beamwidth 14.0 deg.; -3dB @ 6.3, 20.3 deg.  
Sidelobe Gain 0.04 dBi @ Elev Angle = 37.0 deg.  
Front/Sidelobe 18.32 dB

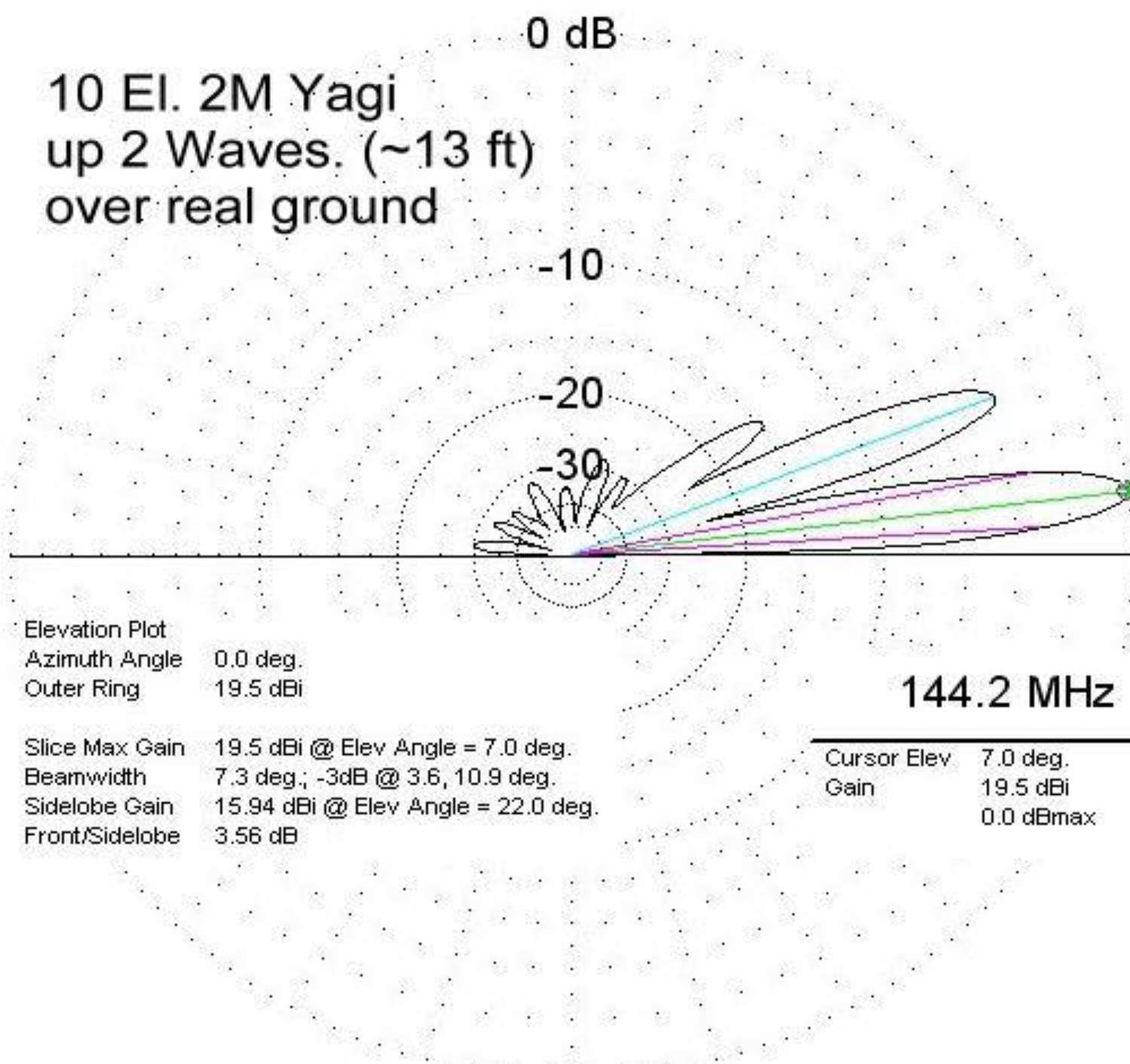
144.2 MHz

Cursor Elev 13.0 deg.  
Gain 18.36 dBi  
0.0 dBmax

10 El. 2M Yagi  
up 1 1/4 Waves. (~8 ft)  
over real ground



10 El. 2M Yagi  
up 2 Waves. (~13 ft)  
over real ground



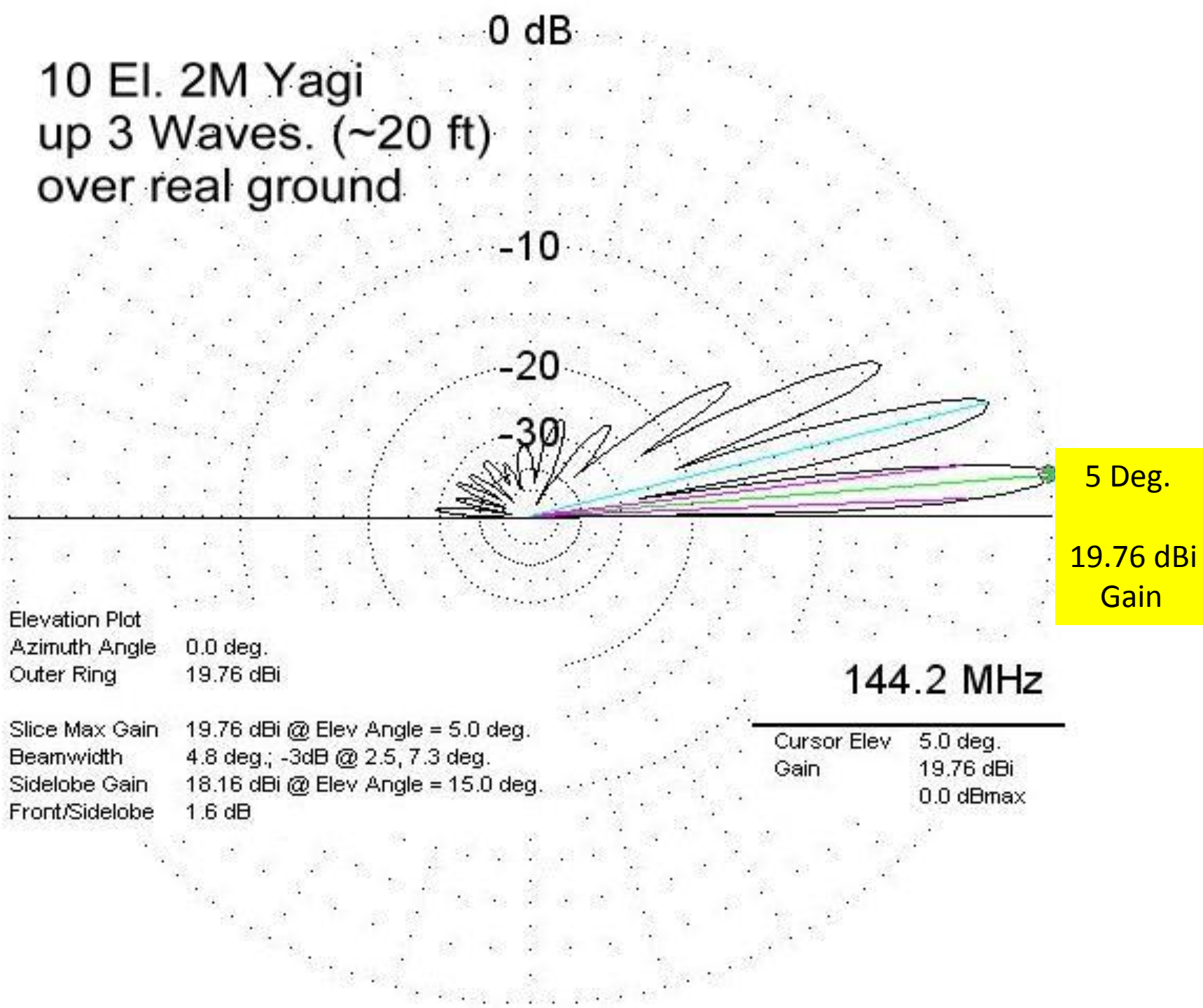
Elevation Plot  
Azimuth Angle 0.0 deg.  
Outer Ring 19.5 dBi

Slice Max Gain 19.5 dBi @ Elev Angle = 7.0 deg.  
Beamwidth 7.3 deg.; -3dB @ 3.6, 10.9 deg.  
Sidelobe Gain 15.94 dBi @ Elev Angle = 22.0 deg.  
Front/Sidelobe 3.56 dB

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Cursor Elev 7.0 deg.  
Gain 19.5 dBi  
0.0 dBmax

10 El. 2M Yagi  
up 3 Waves. (~20 ft)  
over real ground



10 El. 2M Yagi  
up 4 Waves. (~26 ft)  
over real ground

0 dB

-10

-20

-30

4 Deg.

19.79 dBi  
Gain

Elevation Plot

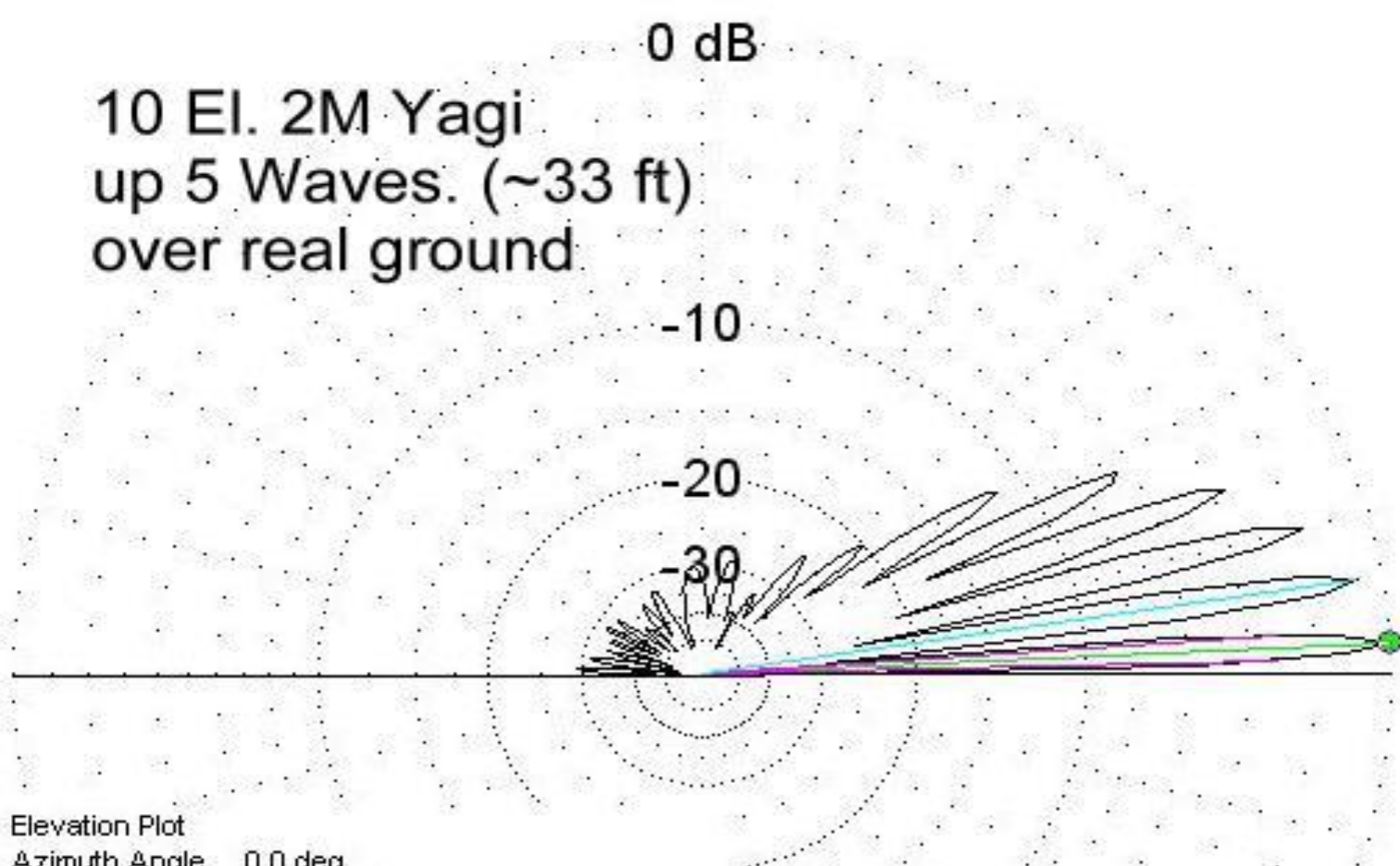
Azimuth Angle 0.0 deg.  
Outer Ring 19.79 dBi

Slice Max Gain 19.79 dBi @ Elev Angle = 4.0 deg.  
Beamwidth 3.6 deg.; -3dB @ 1.9, 5.5 deg.  
Sidelobe Gain 18.92 dBi @ Elev Angle = 11.0 deg.  
Front/Sidelobe 0.87 dB

144.2 MHz

Cursor Elev 4.0 deg.  
Gain 19.79 dBi  
0.0 dBmax

10 El. 2M Yagi  
up 5 Waves. (~33 ft)  
over real ground.



3 Deg.  
19.93  
dBi  
Gain

Elevation Plot

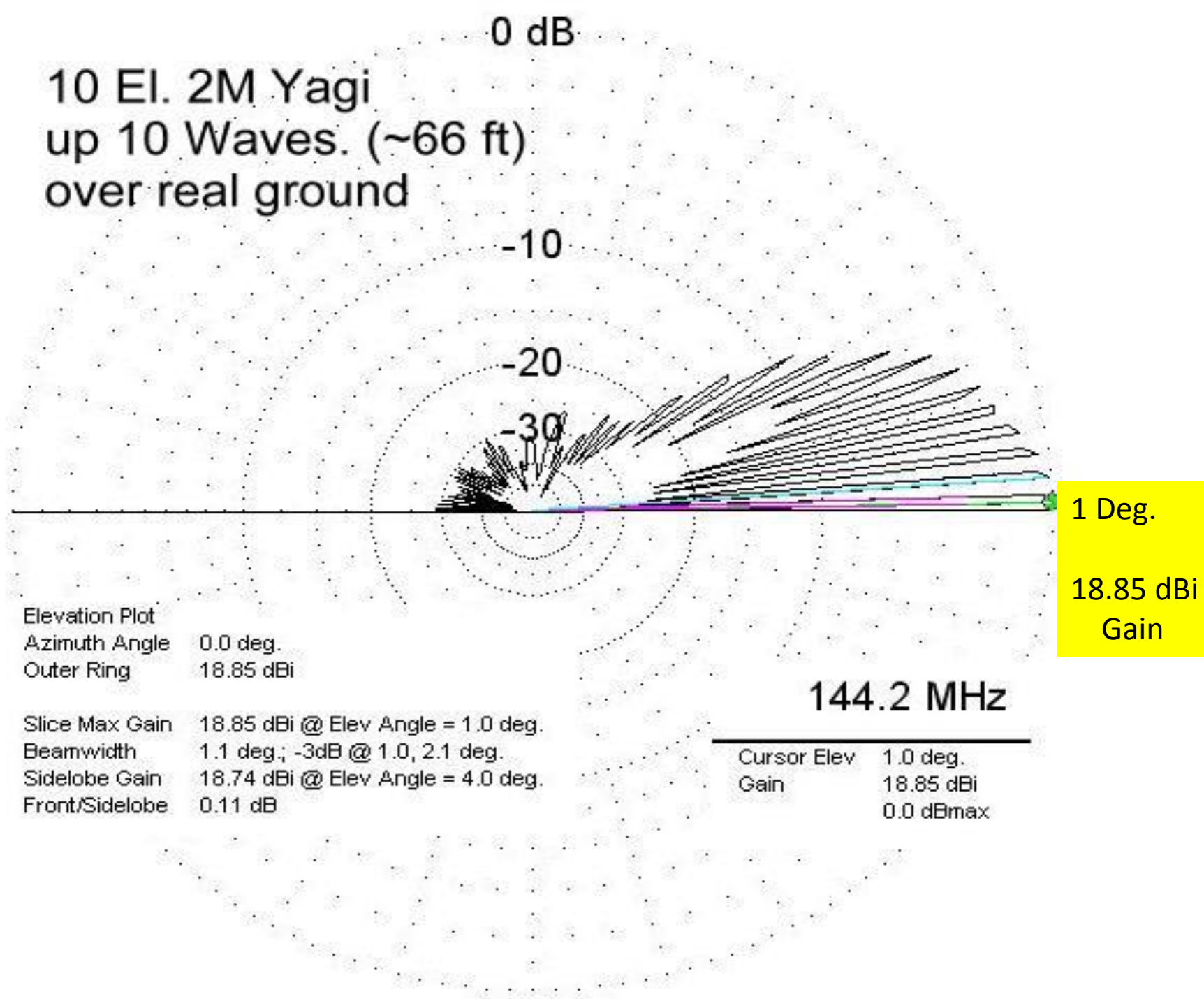
Azimuth Angle 0.0 deg.  
Outer Ring 19.93 dBi

Slice Max Gain 19.93 dBi @ Elev Angle = 3.0 deg.  
Beamwidth 2.7 deg.; -3dB @ 1.6, 4.3 deg.  
Sidelobe Gain 19.28 dBi @ Elev Angle = 9.0 deg.  
Front/Sidelobe 0.66 dB

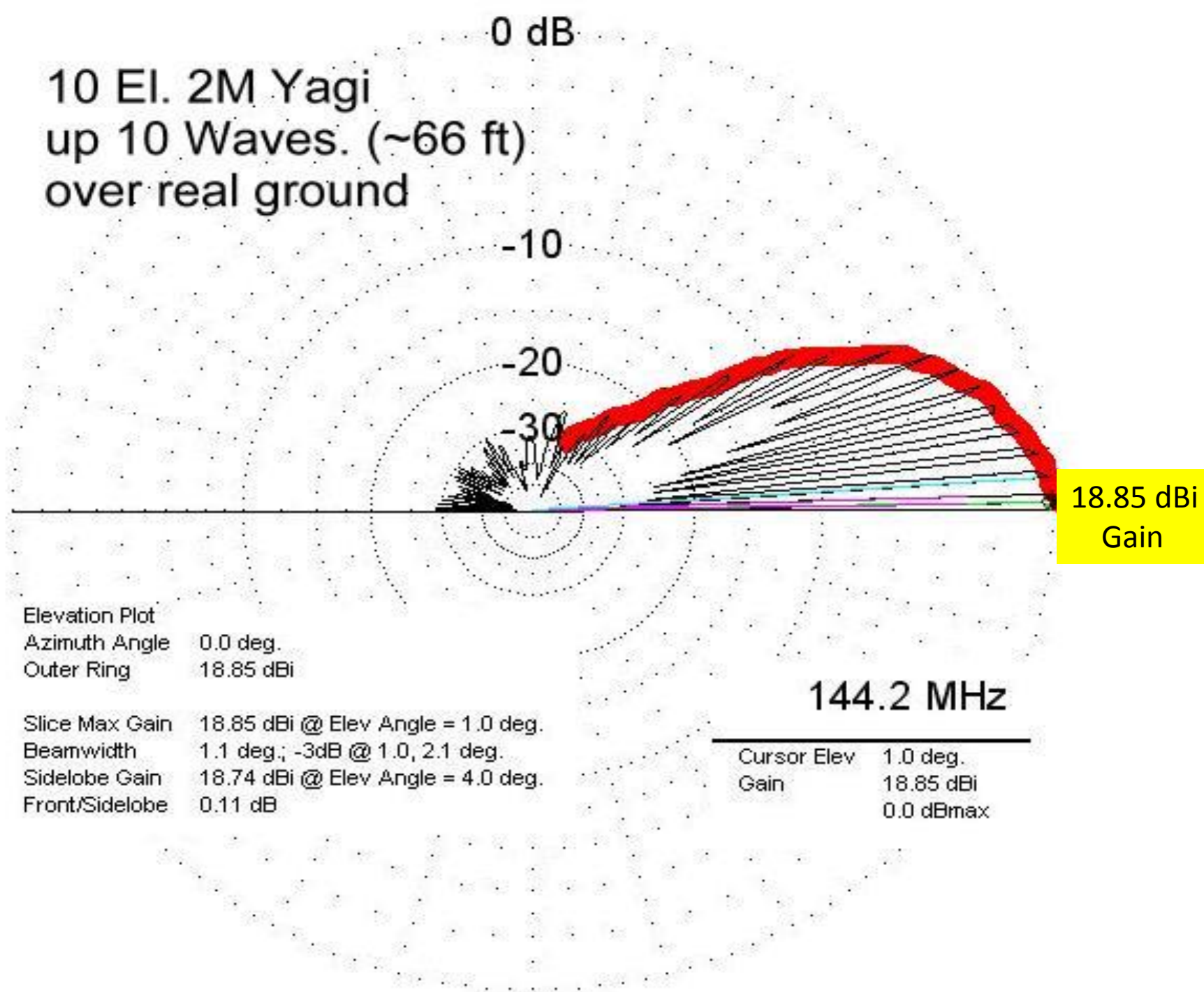
144.2 MHz

Cursor Elev 3.0 deg.  
Gain 19.93 dBi  
0.0 dBmax

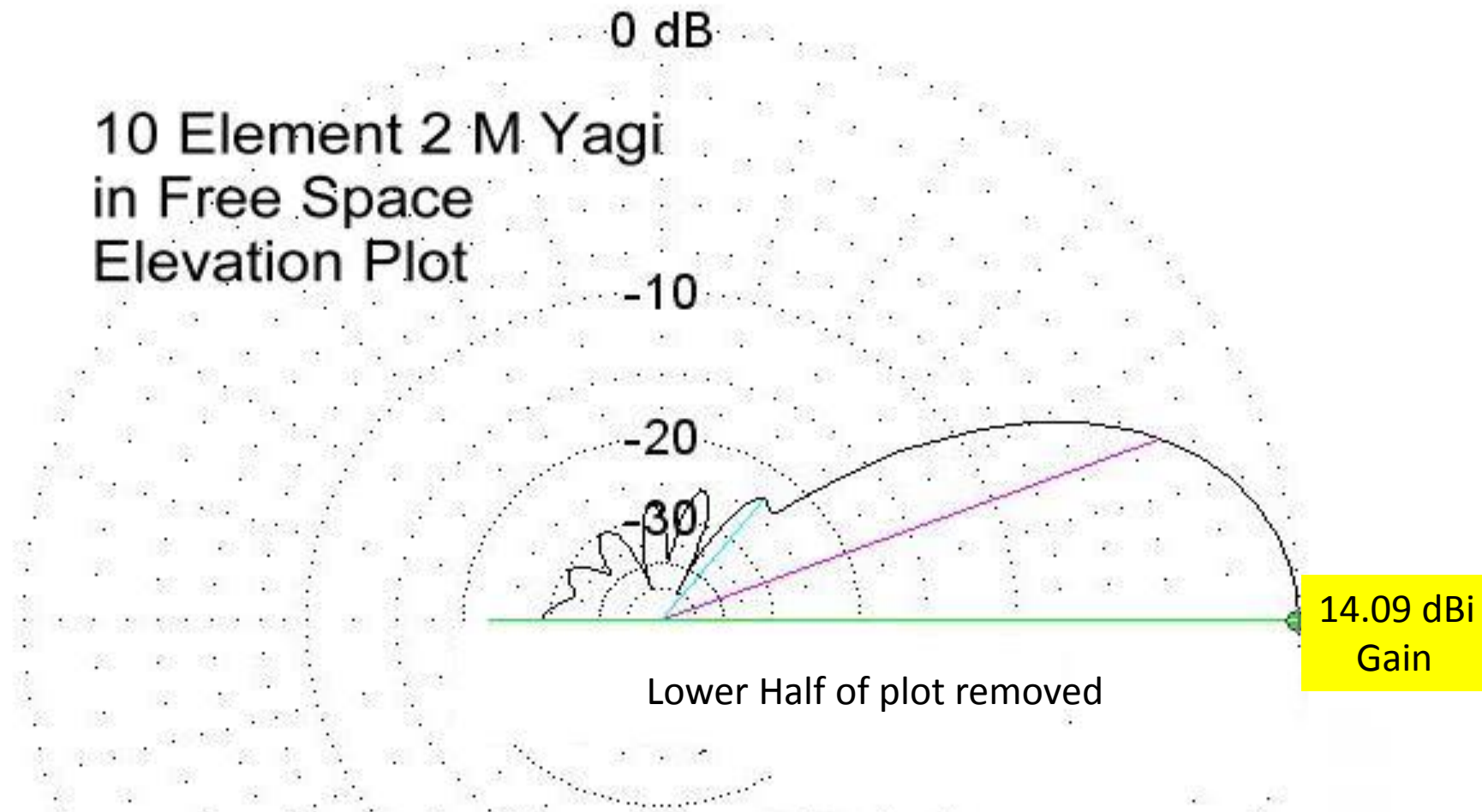
10 El. 2M Yagi  
up 10 Waves. (~66 ft)  
over real ground



10 El. 2M Yagi  
up 10 Waves. (~66 ft)  
over real ground



# 10 Element 2 M Yagi in Free Space Elevation Plot



Elevation Plot  
Azimuth Angle 0.0 deg.  
Outer Ring 14.09 dBi

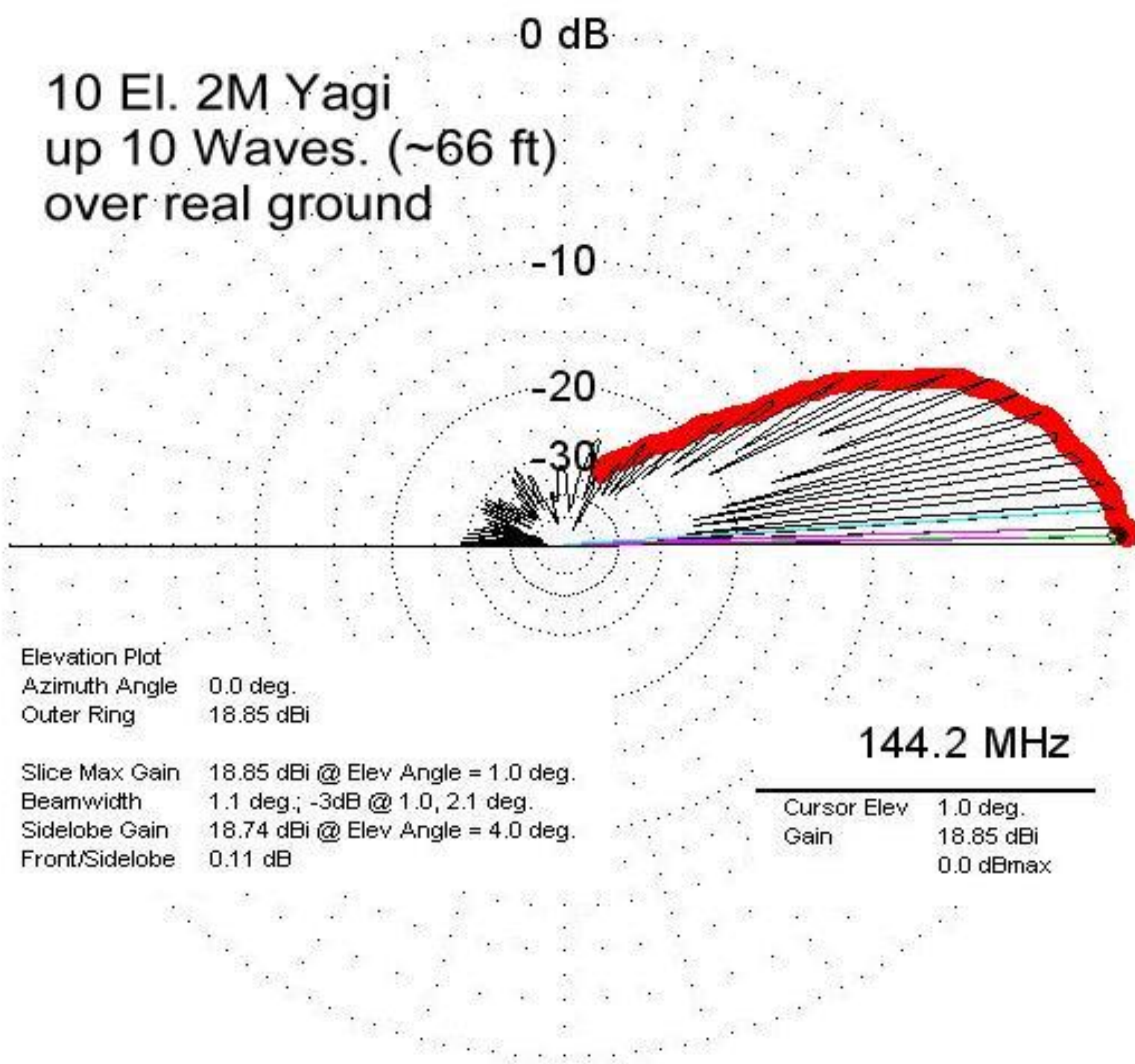
Slice Max Gain 14.09 dBi @ Elev Angle = 0.0 deg.  
Front/Back 28.83 dB  
Beamwidth 43.2 deg.; -3dB @ 338.4, 21.6 deg.  
Sidelobe Gain -8.87 dBi @ Elev Angle = 52.0 deg.  
Front/Sidelobe 22.96 dB

144.2 MHz

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Cursor Elev 0.0 deg.  
Gain 14.09 dBi  
0.0 dBmax

10 El. 2M Yagi  
up 10 Waves. (~66 ft)  
over real ground



**What happens if we flip the antenna to vertical polarization?**

**Note that there is some ground gain, but not as much as with horizontal polarization.**

**Again diminishing returns as we go higher with the antenna.**

# 10 EI 2M Yagi Vertical Pol. up 1/2 Wavelengths

144.2 MHz

Cursor Elev 12.0 deg.  
Gain 11.86 dBi  
0.0 dBmax

Elevation Plot  
Azimuth Angle 0.0 deg.  
Outer Ring 11.86 dBi

Slice Max Gain 11.86 dBi @ Elev Angle = 12.0 deg.  
Beamwidth 15.9 deg.; -3dB @ 5.0, 20.9 deg.  
Sidelobe Gain -13.48 dBi @ Elev Angle = 52.0 deg.  
Front/Sidelobe 25.34 dB

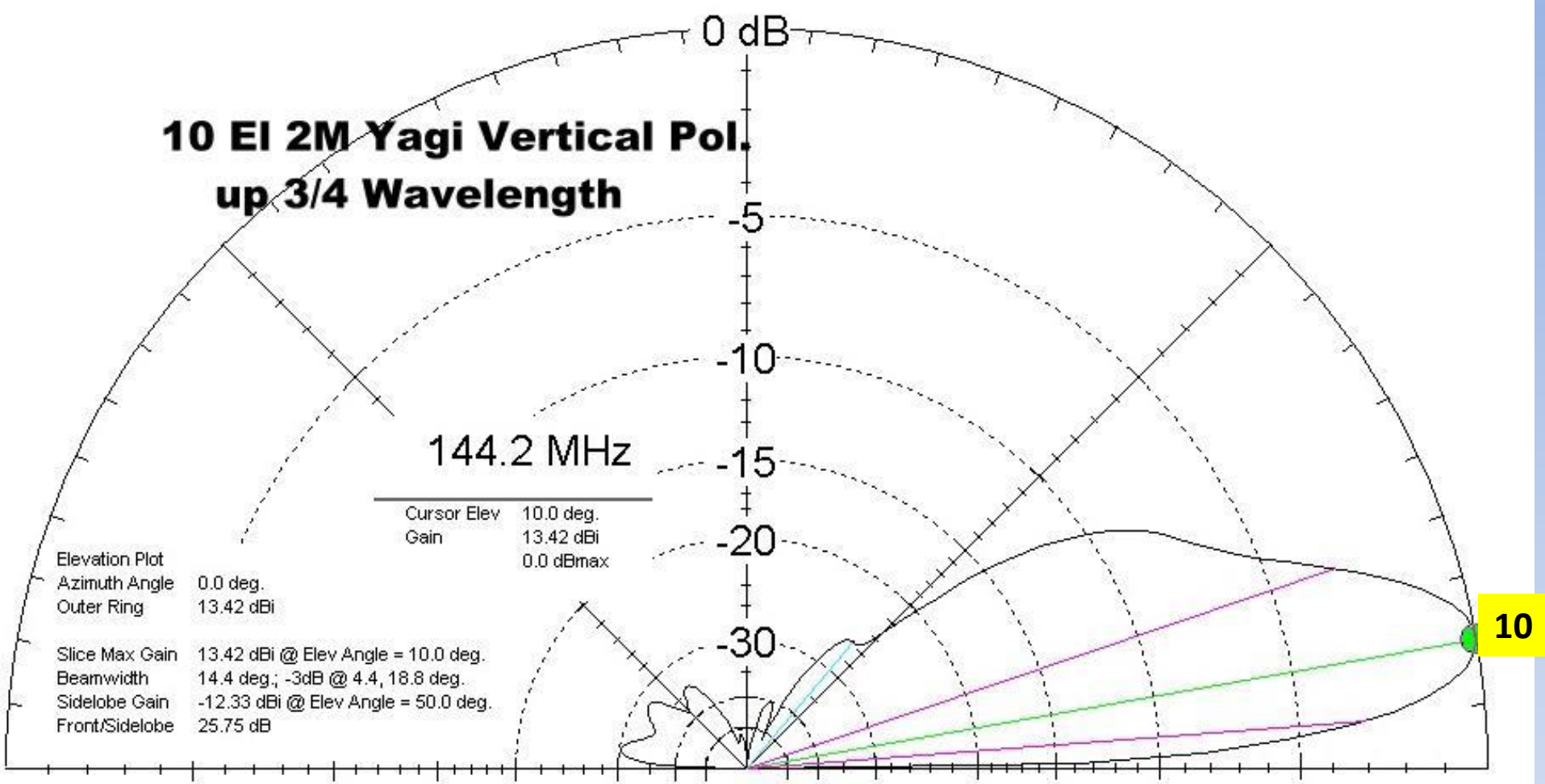
12

Note the lower takeoff angle for height  
Above ground due to vertical polarization.

11.86 dBi  
Gain

H. Pol (15.74 dBi)

Also note lower gain vs. Horizontal Polarization



Notice that we so not see the deep nulls we see with the horizontal antennas. This is due to less interaction with the ground.

13.42 dBi  
Gain  
H. Pol (17.52 dBi)

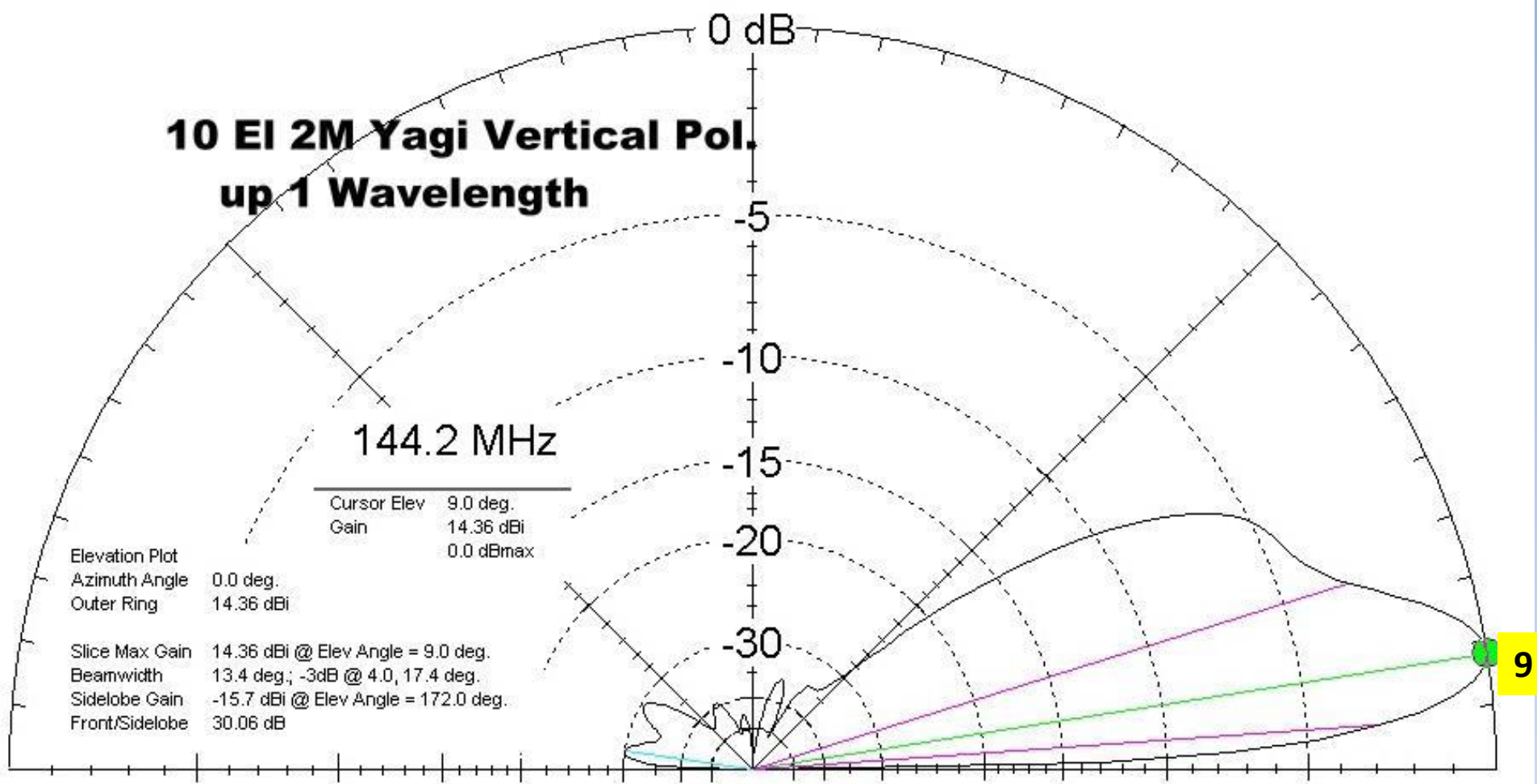
# 10 El 2M Yagi Vertical Pol. up 1 Wavelength

144.2 MHz

Cursor Elev 9.0 deg.  
Gain 14.36 dBi  
0.0 dBmax

Elevation Plot  
Azimuth Angle 0.0 deg.  
Outer Ring 14.36 dBi

Slice Max Gain 14.36 dBi @ Elev Angle = 9.0 deg.  
Beamwidth 13.4 deg.; -3dB @ 4.0, 17.4 deg.  
Sidelobe Gain -15.7 dBi @ Elev Angle = 172.0 deg.  
Front/Sidelobe 30.06 dB



9

14.36 dBi  
Gain

H. Pol (18.36 dBi)

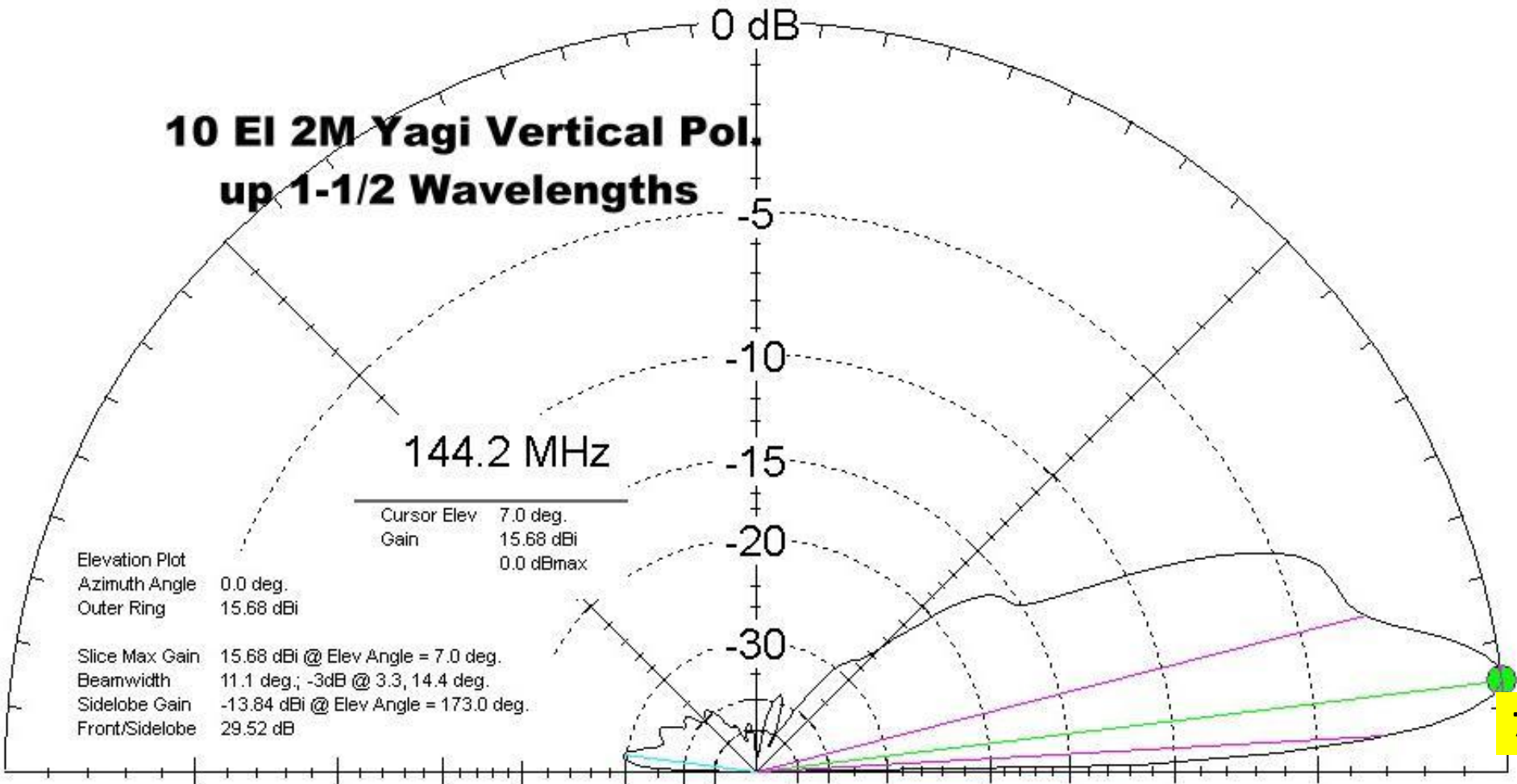
# 10 EI 2M Yagi Vertical Pol. up 1-1/2 Wavelengths

144.2 MHz

Cursor Elev 7.0 deg.  
Gain 15.68 dBi  
0.0 dBmax

Elevation Plot  
Azimuth Angle 0.0 deg.  
Outer Ring 15.68 dBi

Slice Max Gain 15.68 dBi @ Elev Angle = 7.0 deg.  
Beamwidth 11.1 deg.; -3dB @ 3.3, 14.4 deg.  
Sidelobe Gain -13.84 dBi @ Elev Angle = 173.0 deg.  
Front/Sidelobe 29.52 dB



7

15.88 dBi  
Gain

H. Pol (~19 dBi)

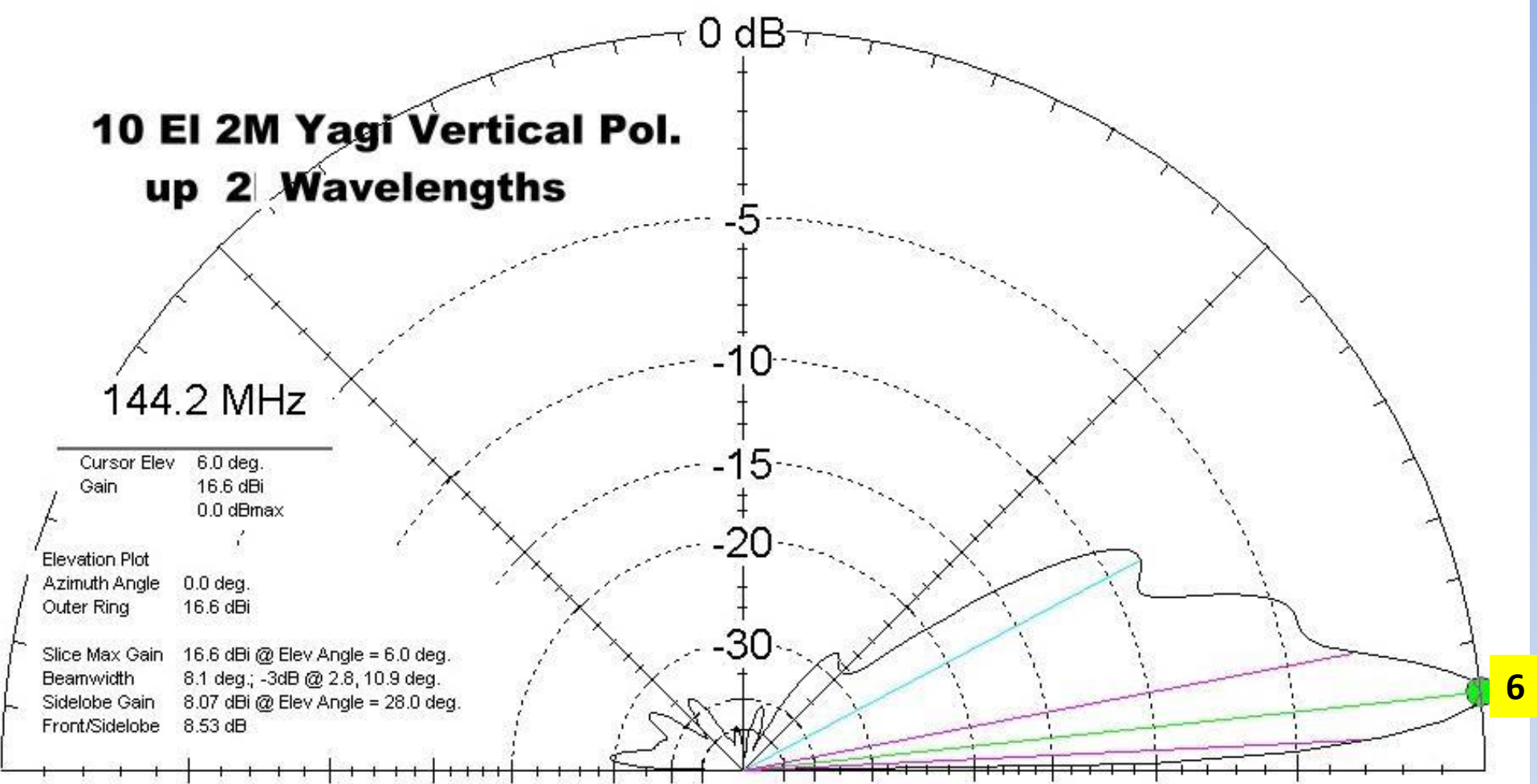
# 10 EI 2M Yagi Vertical Pol. up 2 Wavelengths

144.2 MHz

Cursor Elev 6.0 deg.  
Gain 16.6 dBi  
0.0 dBmax

Elevation Plot  
Azimuth Angle 0.0 deg.  
Outer Ring 16.6 dBi

Slice Max Gain 16.6 dBi @ Elev Angle = 6.0 deg.  
Beamwidth 8.1 deg.; -3dB @ 2.8, 10.9 deg.  
Sidelobe Gain 8.07 dBi @ Elev Angle = 28.0 deg.  
Front/Sidelobe 8.53 dB



16.6 dBi  
Gain

H. Pol (19.5 dBi)

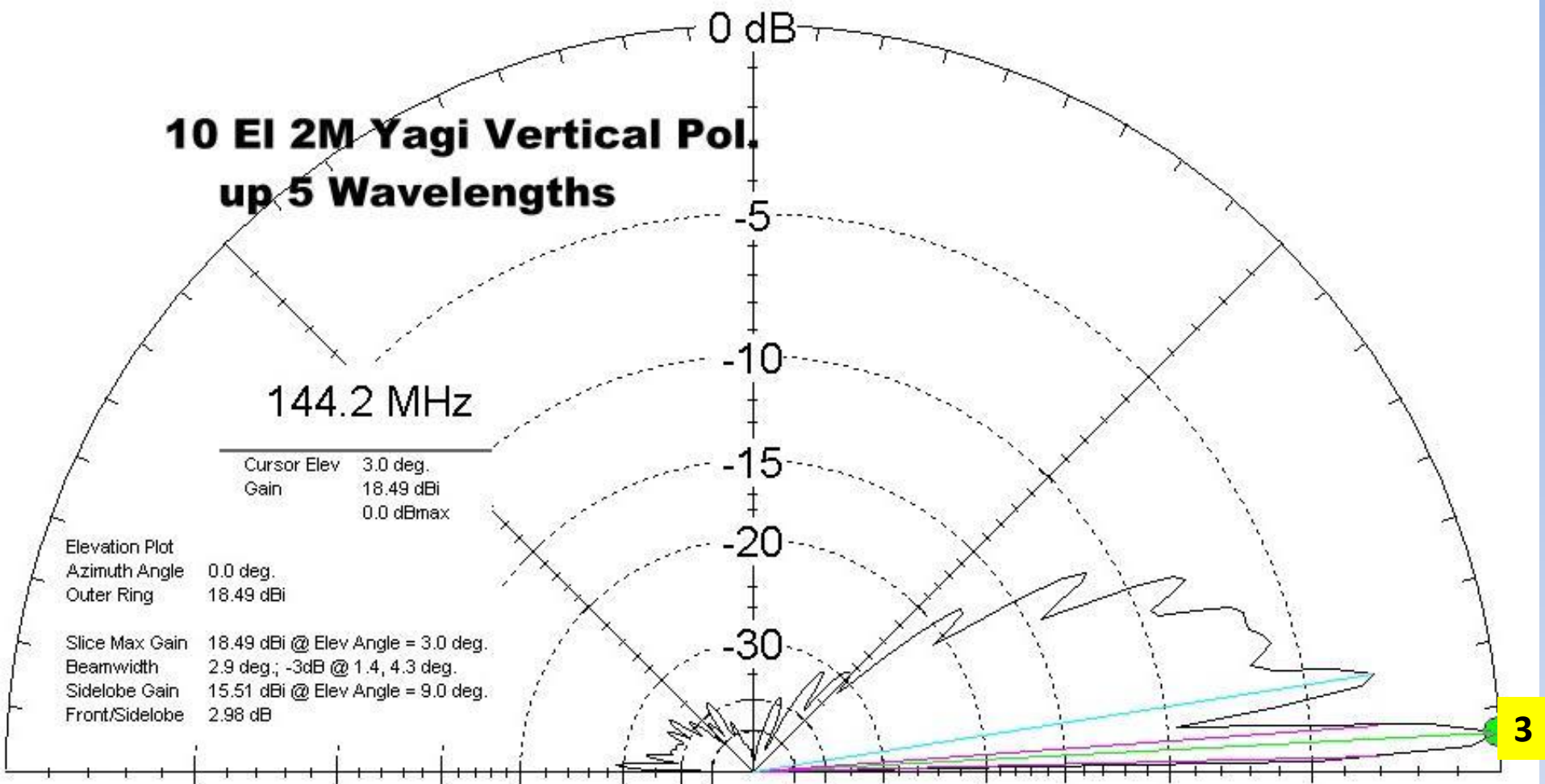
# 10 El 2M Yagi Vertical Pol. up 5 Wavelengths

144.2 MHz

Cursor Elev 3.0 deg.  
Gain 18.49 dBi  
0.0 dBmax

Elevation Plot  
Azimuth Angle 0.0 deg.  
Outer Ring 18.49 dBi

Slice Max Gain 18.49 dBi @ Elev Angle = 3.0 deg.  
Beamwidth 2.9 deg.; -3dB @ 1.4, 4.3 deg.  
Sidelobe Gain 15.51 dBi @ Elev Angle = 9.0 deg.  
Front/Sidelobe 2.98 dB



18.49 dBi  
Gain

H. Pol (19.93 dBi)

# 10 EI 2M Yagi Vertical Pol. up 10 Wavelengths

144.2 MHz

Cursor Elev 1.0 deg.  
Gain 18.34 dBi  
0.0 dBmax

Elevation Plot  
Azimuth Angle 0.0 deg.  
Outer Ring 18.34 dBi

Slice Max Gain 18.34 dBi @ Elev Angle = 1.0 deg.  
Beamwidth 1.2 deg.; -3dB @ 1.0, 2.2 deg.  
Sidelobe Gain 16.92 dBi @ Elev Angle = 4.0 deg.  
Front/Sidelobe 1.42 dB

18.34 dBi  
Gain

H. Pol (18.85 dBi)

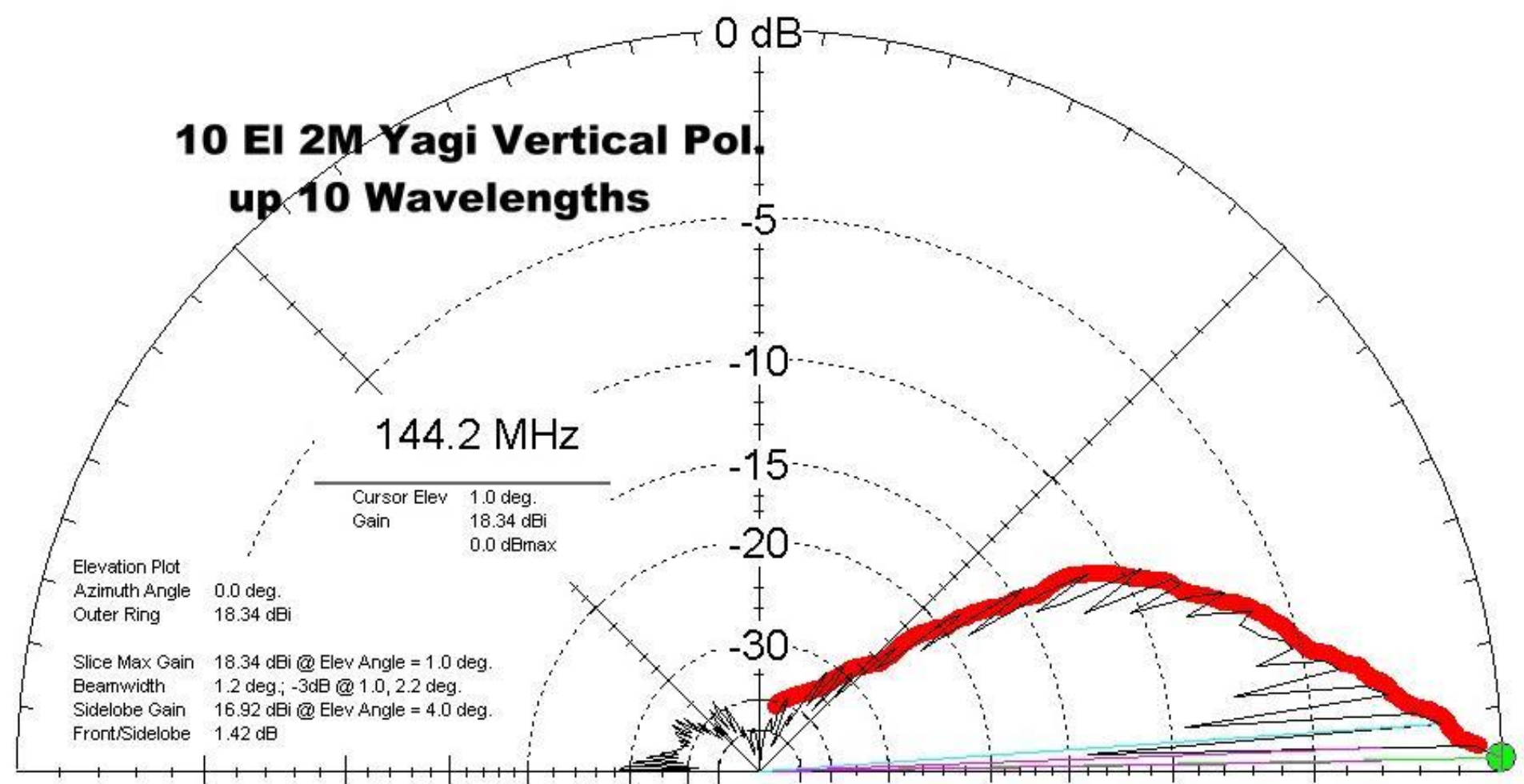
# 10 El 2M Yagi Vertical Pol. up 10 Wavelengths

144.2 MHz

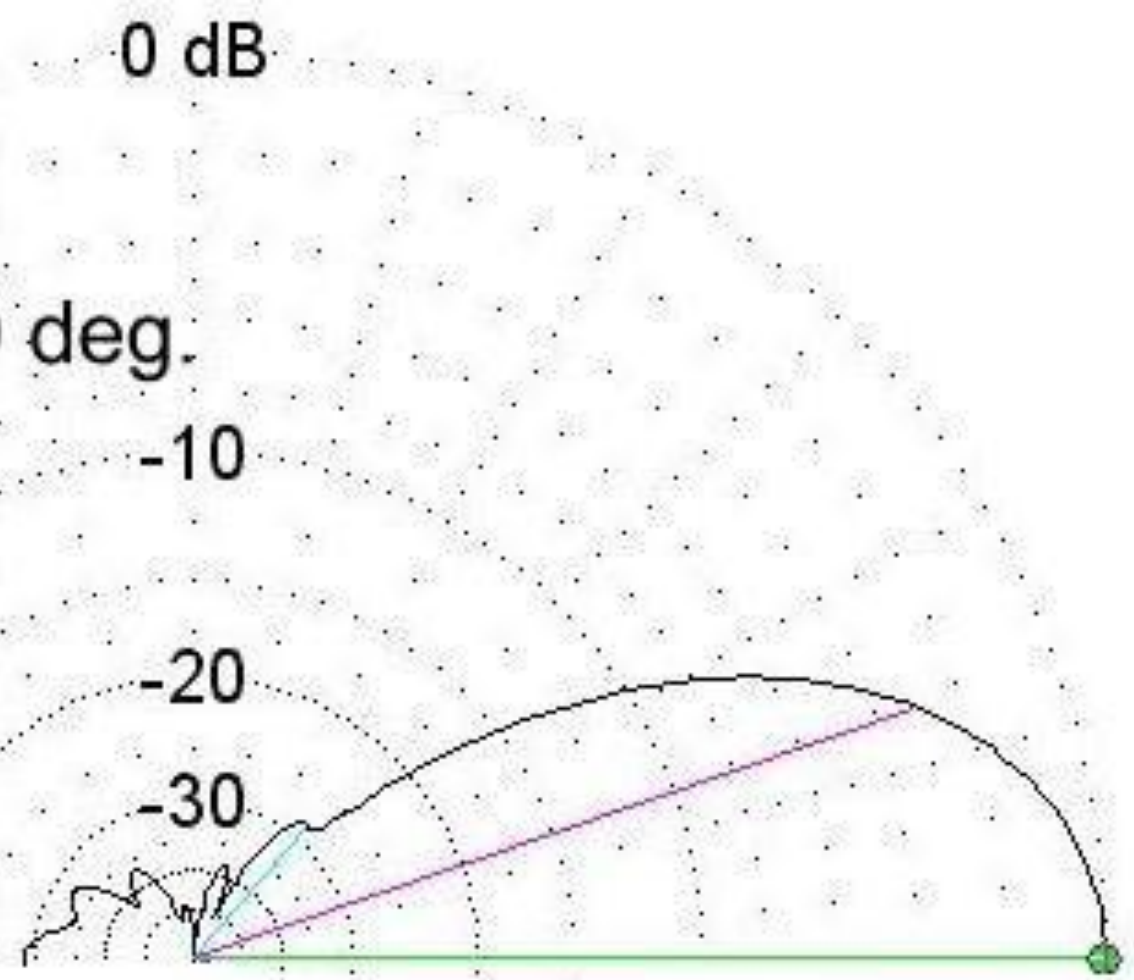
Cursor Elev 1.0 deg.  
Gain 18.34 dBi  
0.0 dBmax

Elevation Plot  
Azimuth Angle 0.0 deg.  
Outer Ring 18.34 dBi

Slice Max Gain 18.34 dBi @ Elev Angle = 1.0 deg.  
Beamwidth 1.2 deg.; -3dB @ 1.0, 2.2 deg.  
Sidelobe Gain 16.92 dBi @ Elev Angle = 4.0 deg.  
Front/Sidelobe 1.42 dB



10 El. 2M Yagi in  
Free Space  
Azimuth Plot at 0 deg.



<b>HEIGHT</b>			<b>FIRST</b>	<b>LOBE</b>
<b>ABOVE</b>	<b>GAIN</b>	<b>IN</b>	<b>TAKEOFF</b>	<b>ANGLE</b>
<b>GROUND</b>				
	<b>10 EL -</b>	<b>10 EL</b>		<b>10 EL</b>
		<b>V POL</b>	<b>10 EL</b>	<b>V POL</b>
<b>Free space</b>	<b>14.1</b>	<b>14.1</b>	<b>0</b>	<b>0</b>
<b>1/2 WAVE</b>	<b>15.7</b>	<b>11.9</b>	<b>19</b>	<b>12</b>
<b>3/4 WAVE</b>	<b>17.5</b>	<b>13.4</b>	<b>16</b>	<b>10</b>
<b>1 WAVE</b>	<b>18.4</b>	<b>14.4</b>	<b>13</b>	<b>9</b>
<b>1-1/2 WAVE</b>	<b>19.2</b>	<b>15.9</b>	<b>9</b>	<b>7</b>
<b>2 WAVE</b>	<b>19.5</b>	<b>16.6</b>	<b>7</b>	<b>6</b>
<b>5 WAVE</b>	<b>19.9</b>	<b>18.5</b>	<b>3</b>	<b>3</b>
<b>10 WAVE</b>	<b>18.9</b>	<b>18.3</b>	<b>1</b>	<b>1</b>

**Let's see how this applies to antennas on various bands...**

**Will the takeoff angle be the same on every band for the same per-cent wavelength above ground?**

**We will look at 2, 6 and 10 Meter yagis at 1, 2, and 5 wavelengths above ground.**

**What would you expect to see?**

**Yagis up one wavelength:**

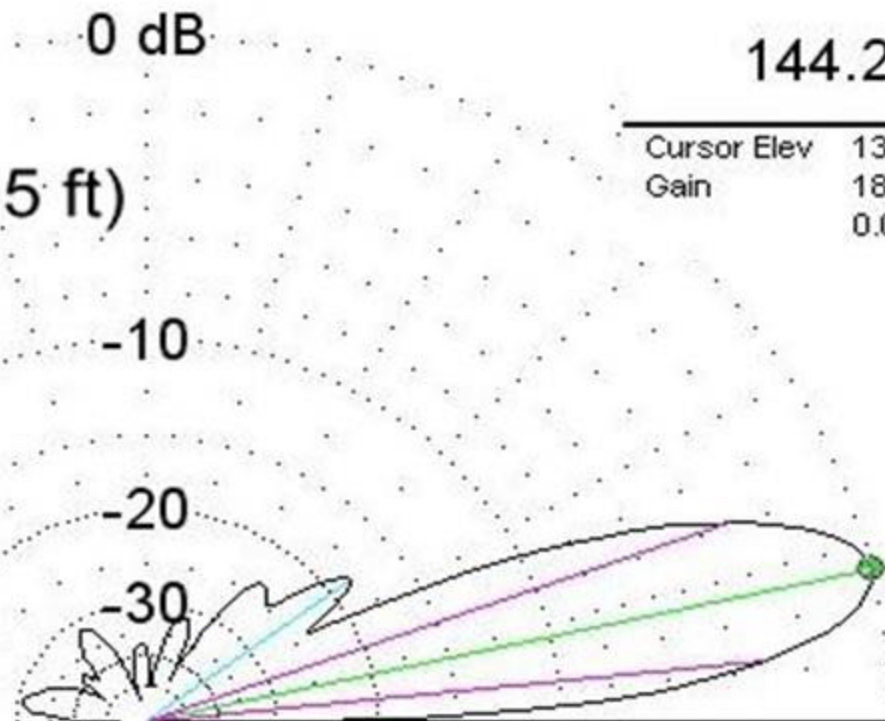
10 El. 2M Yagi  
up 1 Waves. (~6.5 ft)  
over real ground

144.2 MHz

Cursor Elev	13.0 deg.
Gain	18.36 dBi
	0.0 dBmax

Elevation Plot  
Azimuth Angle 0.0 deg.  
Outer Ring 18.36 dBi

Slice Max Gain 18.36 dBi @ Elev Angle = 13.0 deg.  
Beamwidth 14.0 deg.; -3dB @ 6.3, 20.3 deg.  
Sidelobe Gain 0.04 dBi @ Elev Angle = 37.0 deg.  
Front/Sidelobe 18.32 dB



**13 degrees**  
**18.36 dBi**

**5 EL 2 m Yagi  
up 1 Wave (~ 6 ft)  
Elevation plot**

144.2 MHz

Elevation Plot  
Azimuth Angle 0.0 deg.  
Outer Ring 15.47 dBi

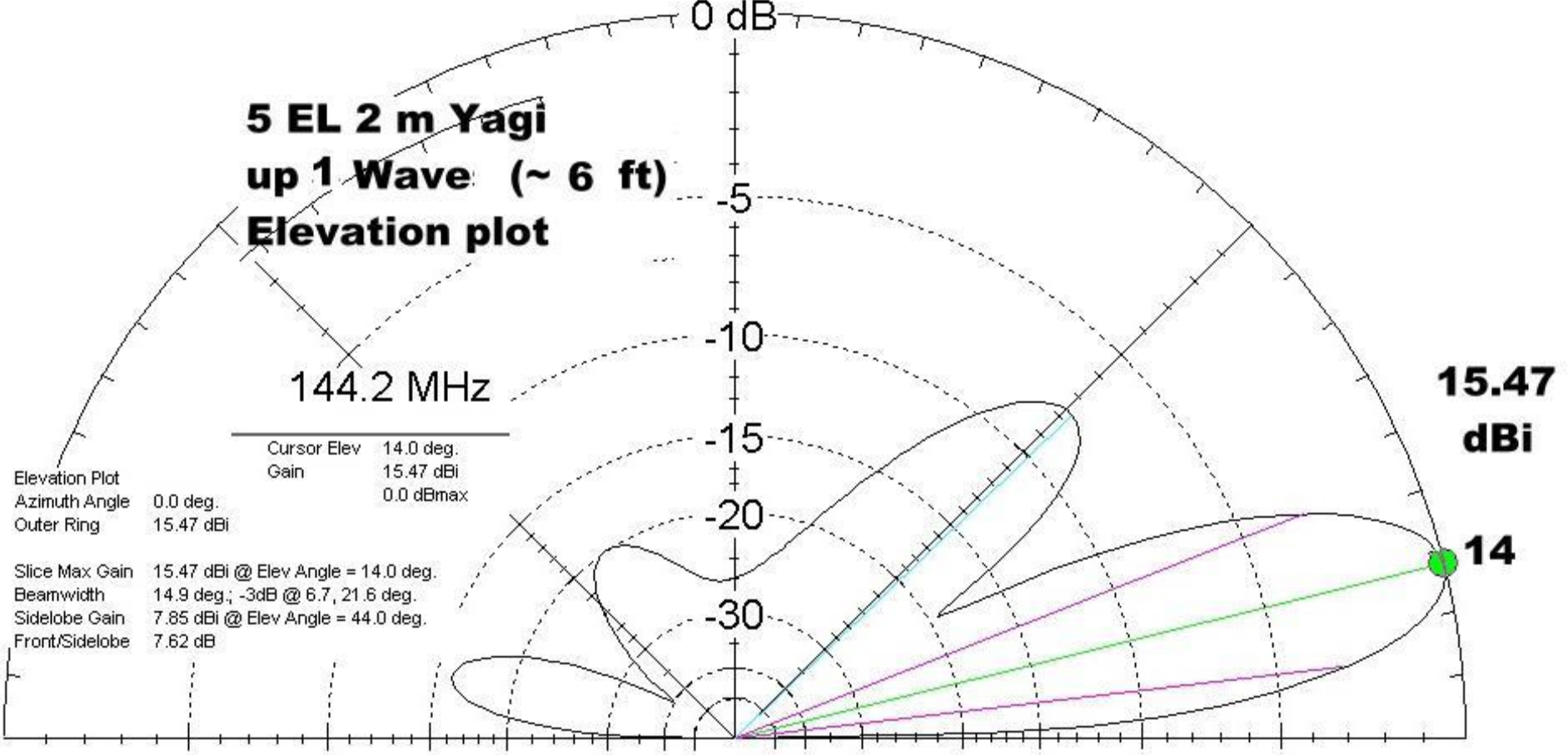
Cursor Elev 14.0 deg.  
Gain 15.47 dBi  
0.0 dBmax

Slice Max Gain 15.47 dBi @ Elev Angle = 14.0 deg.  
Beamwidth 14.9 deg.; -3dB @ 6.7, 21.6 deg.  
Sidelobe Gain 7.85 dBi @ Elev Angle = 44.0 deg.  
Front/Sidelobe 7.62 dB

**15.47  
dBi**

**14**

**14 degrees  
15.47 dBi**



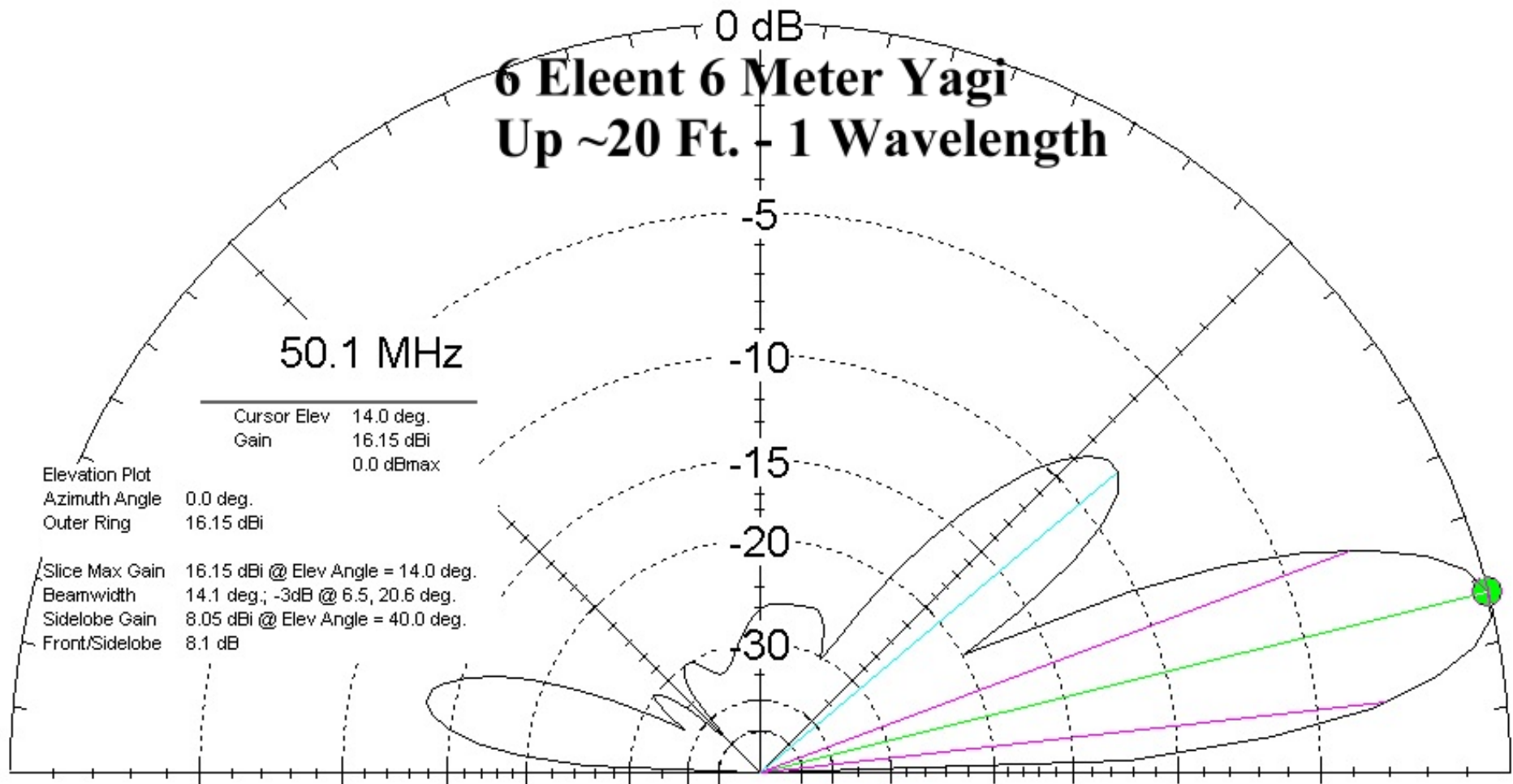
# 6 Element 6 Meter Yagi Up ~20 Ft. - 1 Wavelength

50.1 MHz

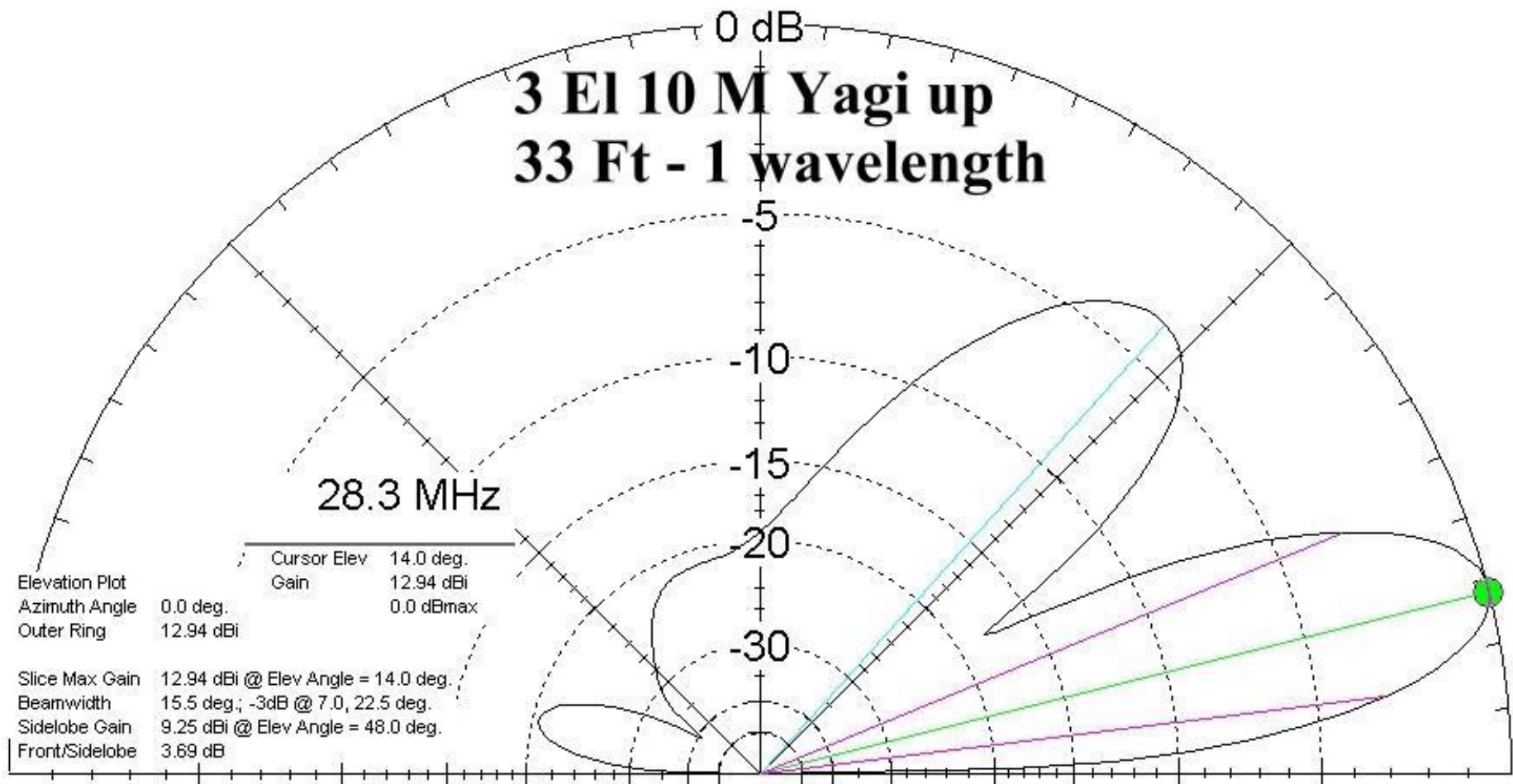
Cursor Elev 14.0 deg.  
Gain 16.15 dBi  
0.0 dBmax

Elevation Plot  
Azimuth Angle 0.0 deg.  
Outer Ring 16.15 dBi

Slice Max Gain 16.15 dBi @ Elev Angle = 14.0 deg.  
Beamwidth 14.1 deg.; -3dB @ 6.5, 20.6 deg.  
Sidelobe Gain 8.05 dBi @ Elev Angle = 40.0 deg.  
Front/Sidelobe 8.1 dB



**14 degrees**  
**16.15 dBi**



**14 degrees**  
**12.94 dBi**

**NOTE: a 40 M dipole up 1 wavelength**  
**Has its major lobe at 15 degrees**

**Let's go up to two wavelengths:**

# 10 El. 2M Yagi up 2 Waves. (~13 ft) over real ground

0 dB

144.2 MHz

Cursor Elev	7.0 deg.
Gain	19.5 dBi
	0.0 dBmax

Elevation Plot  
Azimuth Angle 0.0 deg.  
Outer Ring 19.5 dBi

Slice Max Gain 19.5 dBi @ Elev Angle = 7.0 deg.  
Beamwidth 7.3 deg.; -3dB @ 3.6, 10.9 deg.  
Sidelobe Gain 15.94 dBi @ Elev Angle = 22.0 deg.  
Front/Sidelobe 3.56 dB

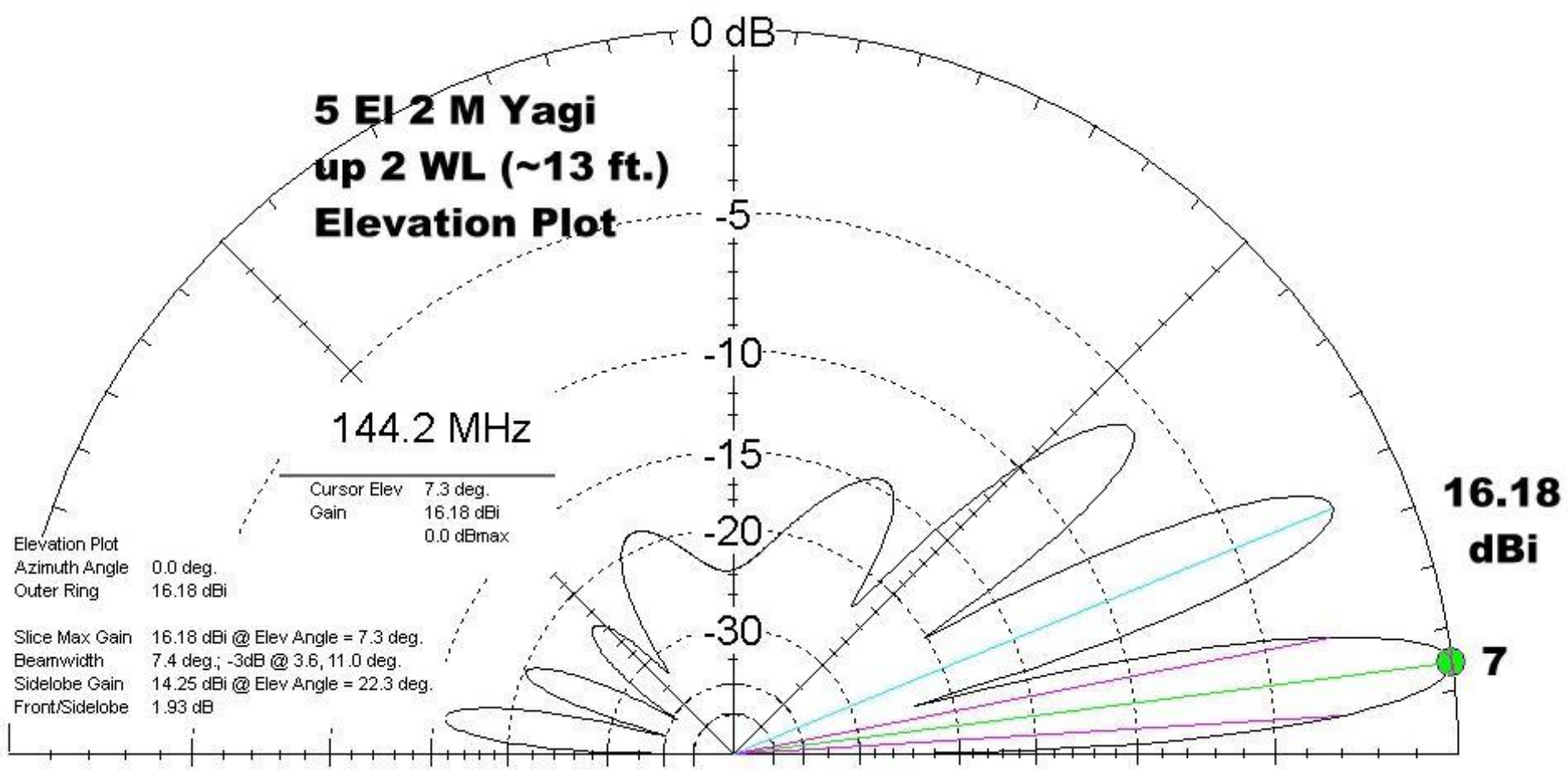
-10

-20

-30



**7 Deg.**  
**19.5 dBi**



**7 degrees**  
**16.18 dBi**

# 6 Meter Yagi UP 2 Wavelengths

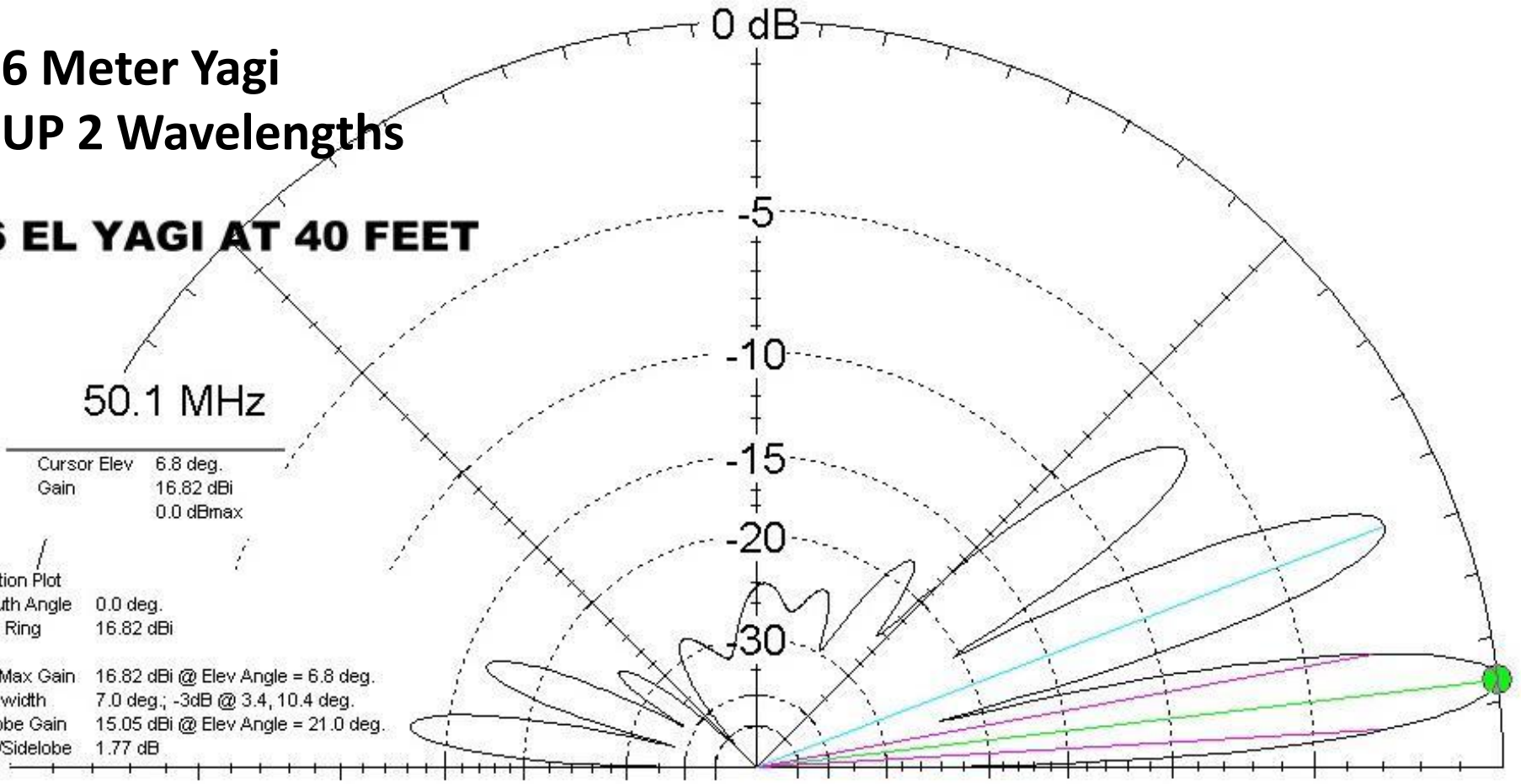
## 6 EL YAGI AT 40 FEET

50.1 MHz

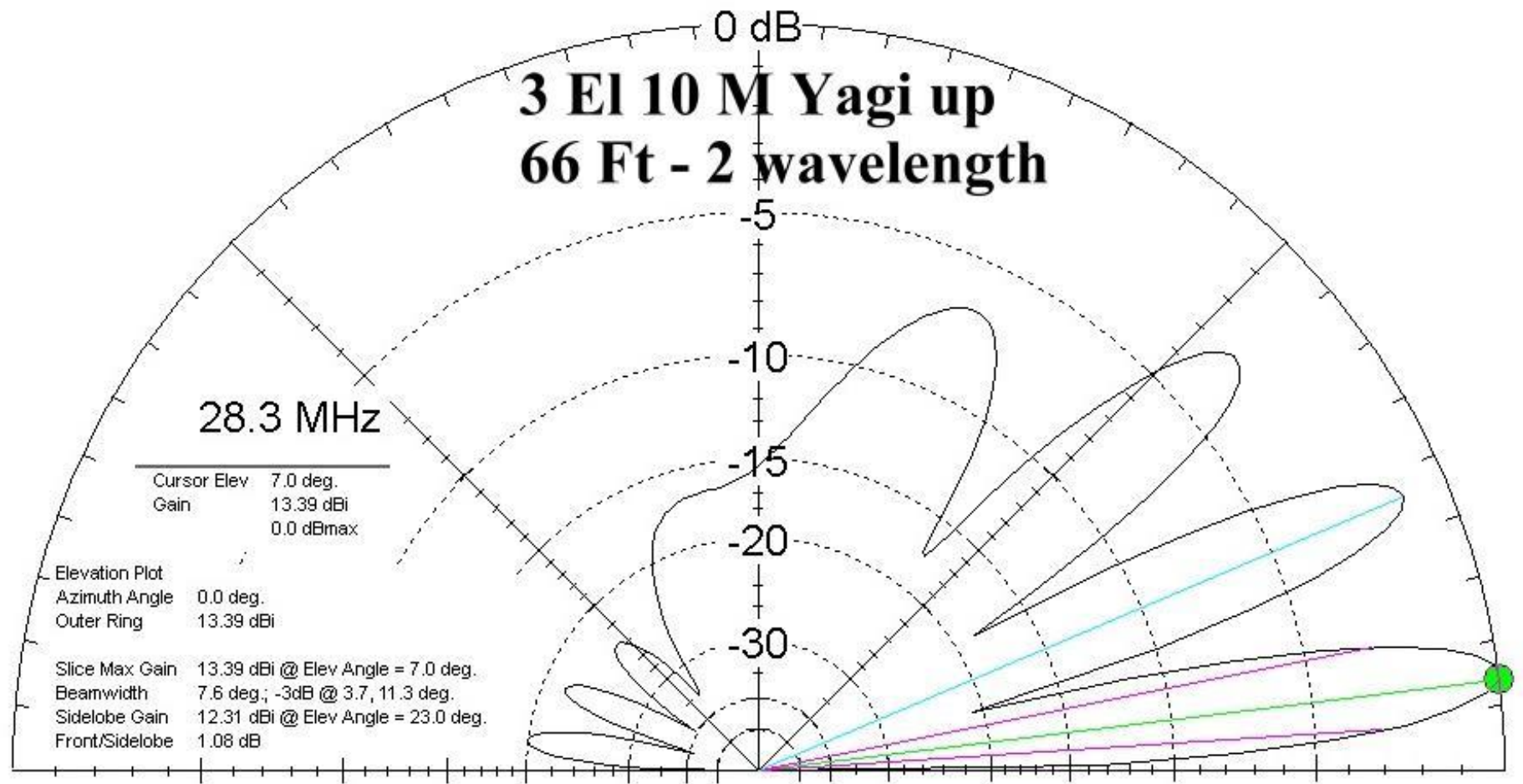
Cursor Elev 6.8 deg.  
Gain 16.82 dBi  
0.0 dBmax

Elevation Plot  
Azimuth Angle 0.0 deg.  
Outer Ring 16.82 dBi

Slice Max Gain 16.82 dBi @ Elev Angle = 6.8 deg.  
Beamwidth 7.0 deg.; -3dB @ 3.4, 10.4 deg.  
Sidelobe Gain 15.05 dBi @ Elev Angle = 21.0 deg.  
Front/Sidelobe 1.77 dB



**6.8 Deg.  
16.8 dBi**



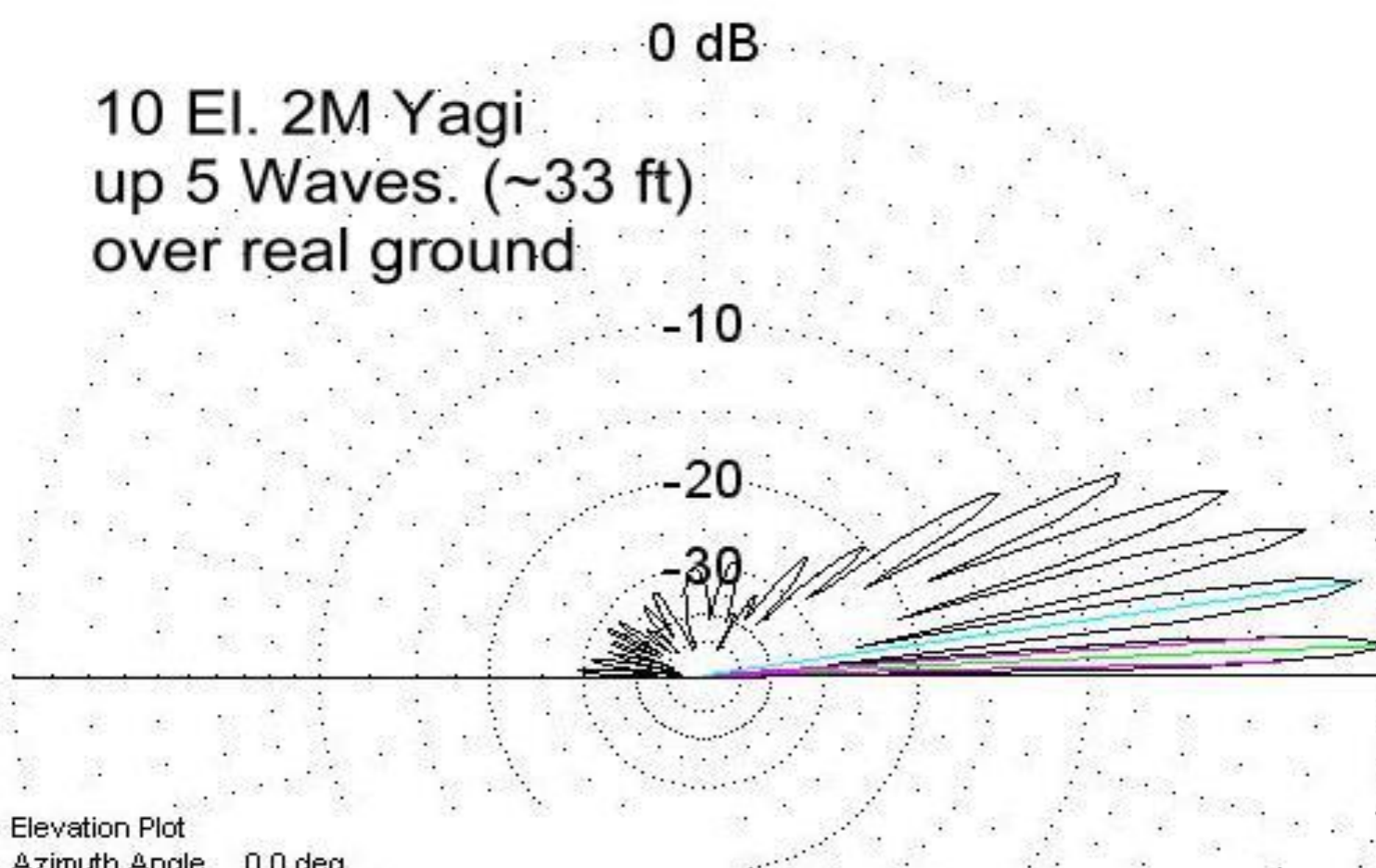
**7 degrees**  
**13.39 dBi**

**NOTE: a 40 Meter dipole up 2 wavelengths  
Has its major lobe at 7 degrees**

**Now, what would you expect**

**if we go up five wavelengths?**

10 El. 2M Yagi  
up 5 Waves. (~33 ft)  
over real ground



Elevation Plot

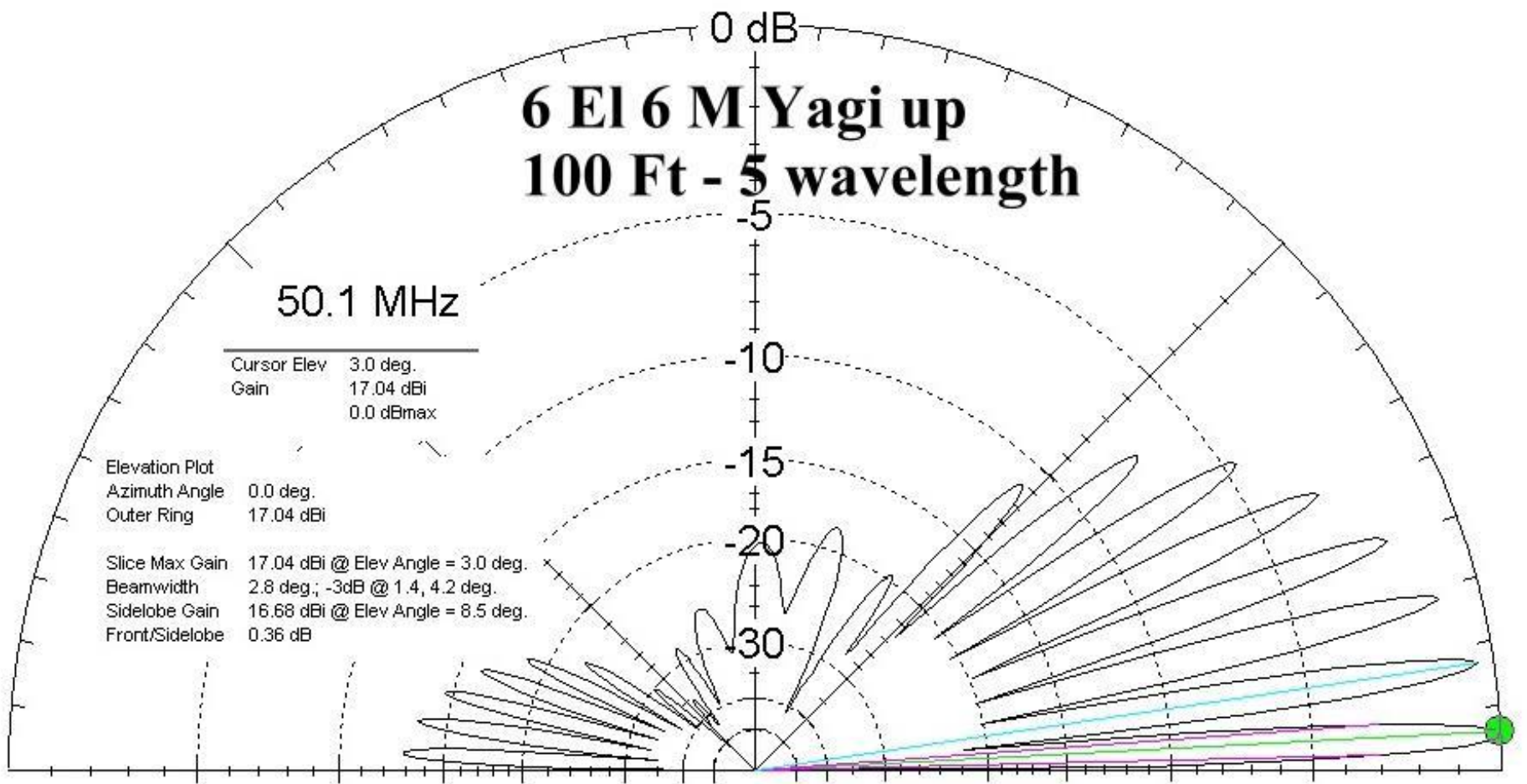
Azimuth Angle 0.0 deg.  
Outer Ring 19.93 dBi

Slice Max Gain 19.93 dBi @ Elev Angle = 3.0 deg.  
Beamwidth 2.7 deg.; -3dB @ 1.6, 4.3 deg.  
Sidelobe Gain 19.28 dBi @ Elev Angle = 9.0 deg.  
Front/Sidelobe 0.66 dB

144.2 MHz

---

Cursor Elev 3.0 deg.  
Gain 19.93 dBi  
0.0 dBmax



**3 Degrees**  
**17 dBi**

**Just for fun, I have modeled my**

**4 bay 2 meter array used for EME**

**4 x 20 elements in a 12 foot square**

**I only show the Horizontal  
Polarization plots...**

**The lower 2 antennas are  
up 8 ft and the upper 2 are  
up 20 ft... The effective  
array height is 14 ft. or  
just over 2 WL high.**



# 40 EL EME ARRAY

## 0 degrees elevaion

144.2 MHz

Cursor Elev 5.0 deg.  
Gain 24.25 dBi  
0.0 dBmax

Elevation Plot  
Azimuth Angle 0.0 deg.  
Outer Ring 24.25 dBi

Slice Max Gain 24.25 dBi @ Elev Angle = 5.0 deg.  
Beamwidth 5.2 deg.; -3dB @ 2.5, 7.7 deg.  
Sidelobe Gain 17.78 dBi @ Elev Angle = 30.0 deg.  
Front/Sidelobe 6.47 dB

0 dB

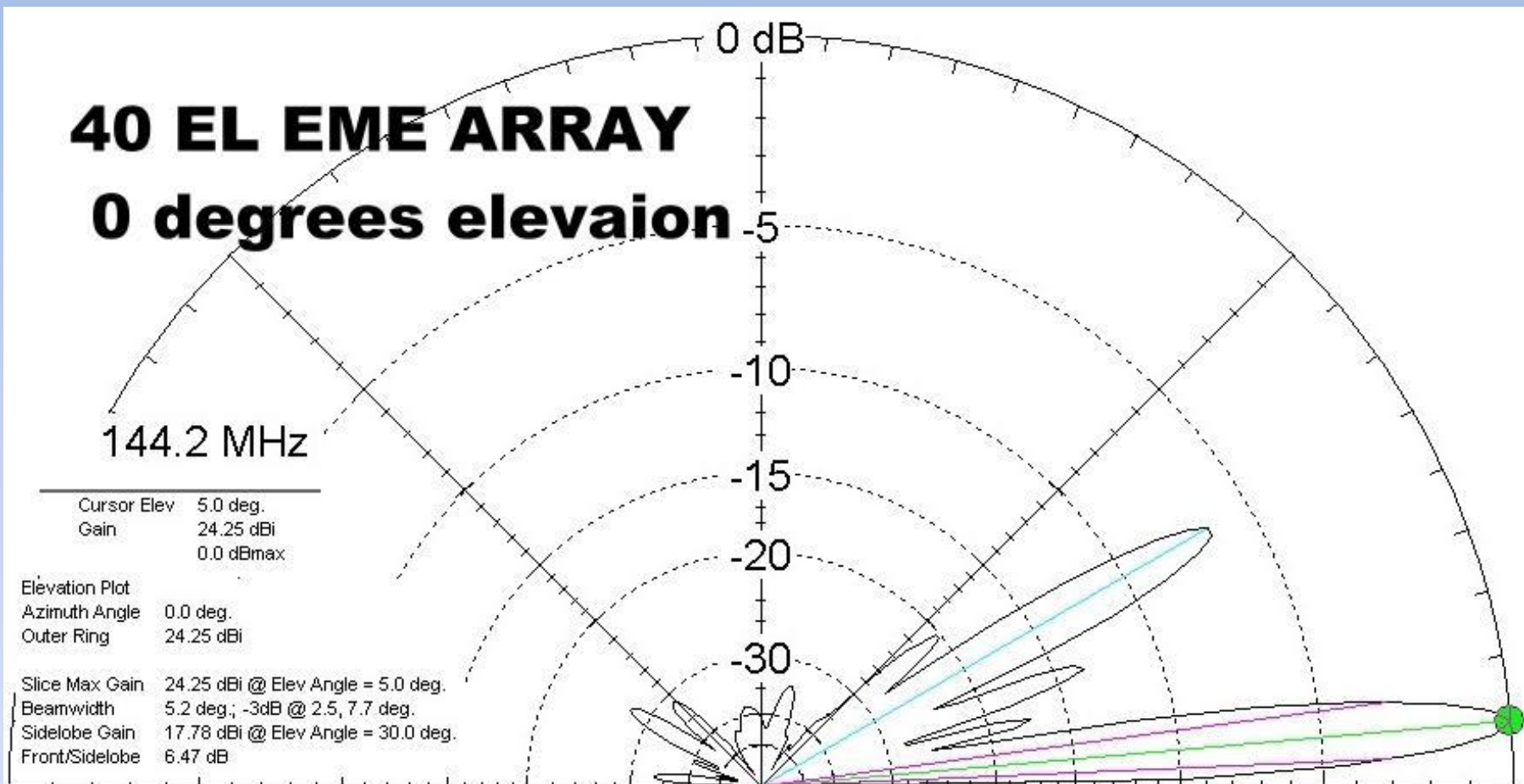
-5

-10

-15

-20

-30



# 40 EL EME ARRAY

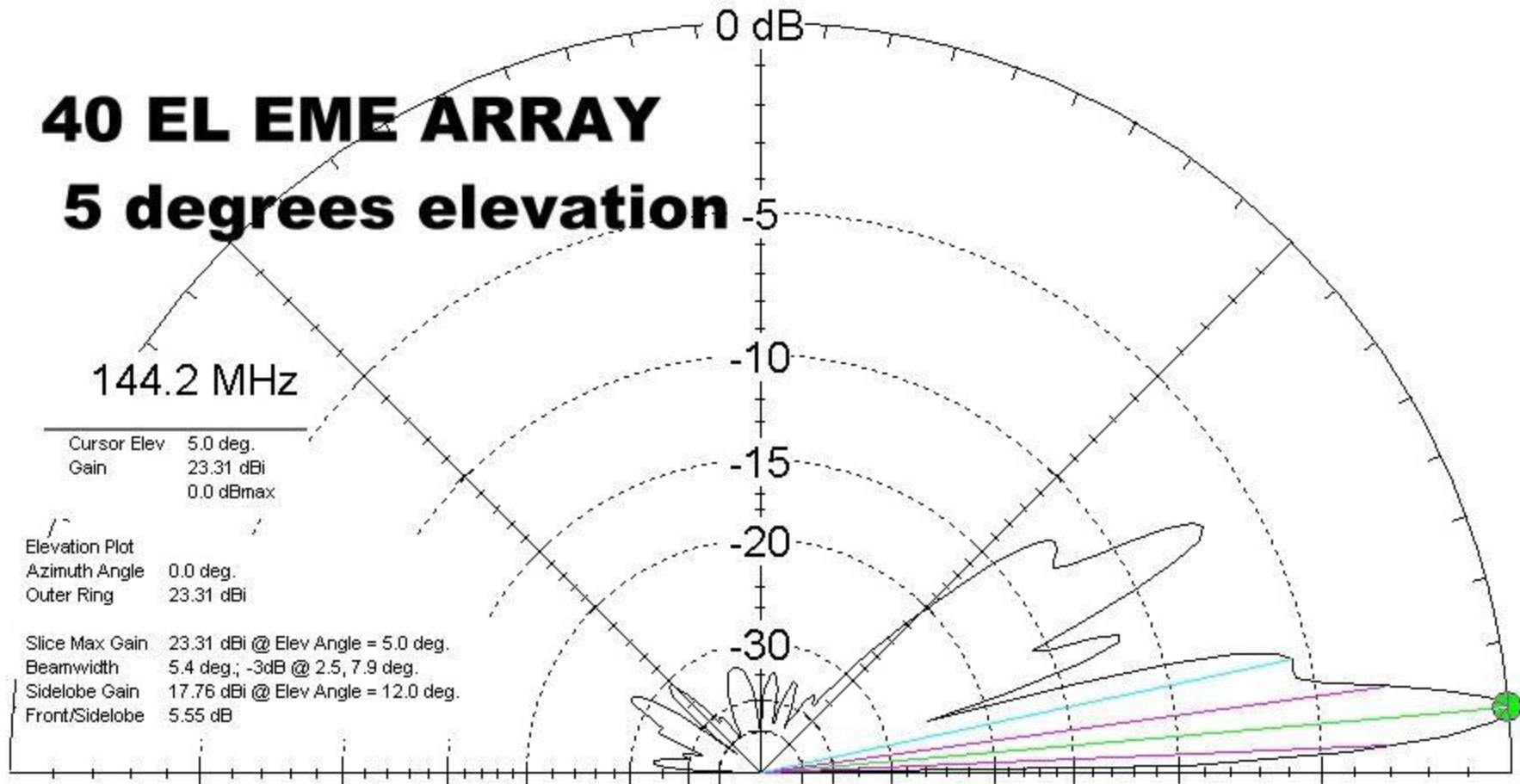
## 5 degrees elevation

144.2 MHz

Cursor Elev 5.0 deg.  
Gain 23.31 dBi  
0.0 dBmax

Elevation Plot  
Azimuth Angle 0.0 deg.  
Outer Ring 23.31 dBi

Slice Max Gain 23.31 dBi @ Elev Angle = 5.0 deg.  
Beamwidth 5.4 deg.; -3dB @ 2.5, 7.9 deg.  
Sidelobe Gain 17.76 dBi @ Elev Angle = 12.0 deg.  
Front/Sidelobe 5.55 dB



# 40 EL EME ARRAY

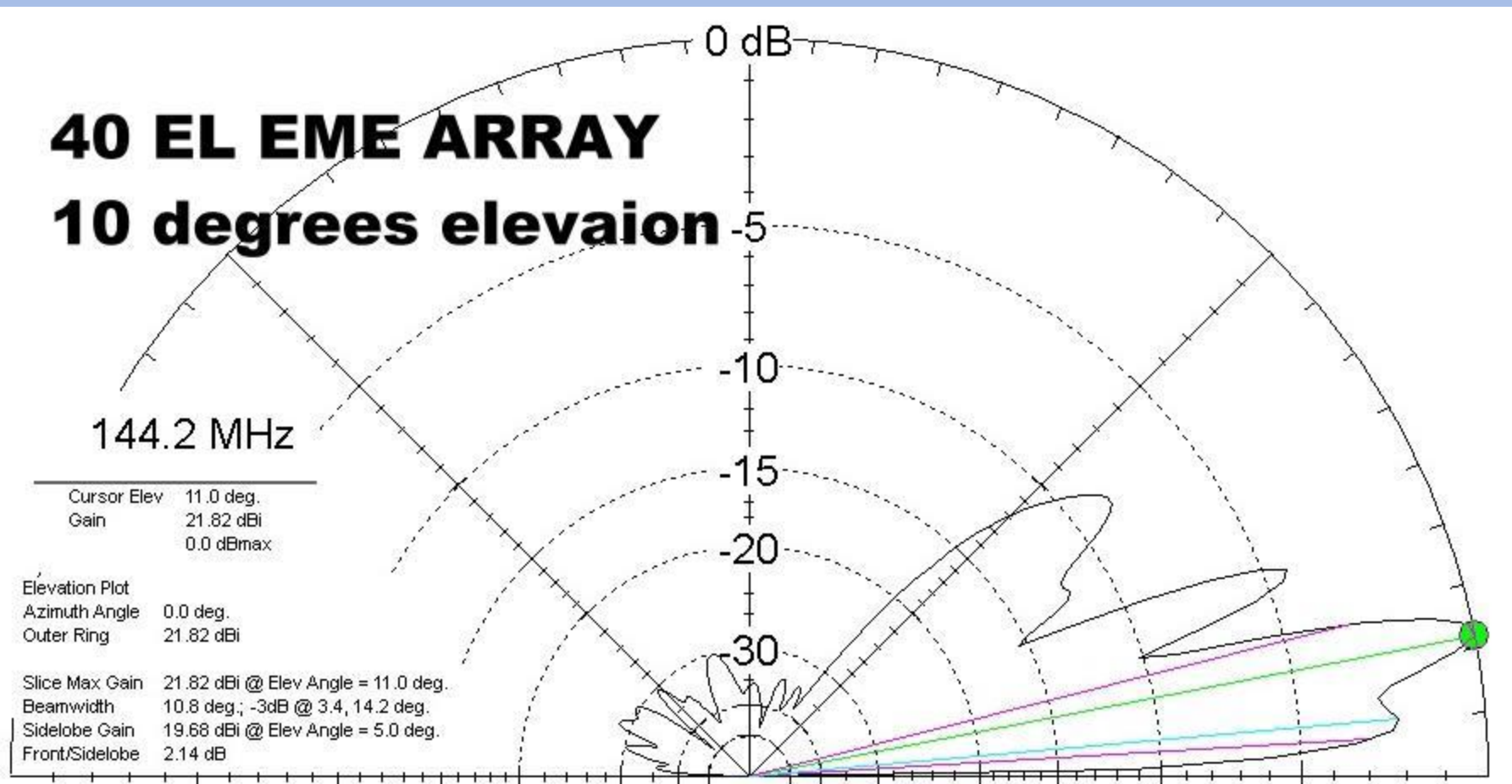
## 10 degrees elevaion

144.2 MHz

Cursor Elev	11.0 deg.
Gain	21.82 dBi
	0.0 dBmax

Elevation Plot	
Azimuth Angle	0.0 deg.
Outer Ring	21.82 dBi

Slice Max Gain	21.82 dBi @ Elev Angle = 11.0 deg.
Beamwidth	10.8 deg.; -3dB @ 3.4, 14.2 deg.
Sidelobe Gain	19.68 dBi @ Elev Angle = 5.0 deg.
Front/Sidelobe	2.14 dB



# 40 EL EME ARRAY

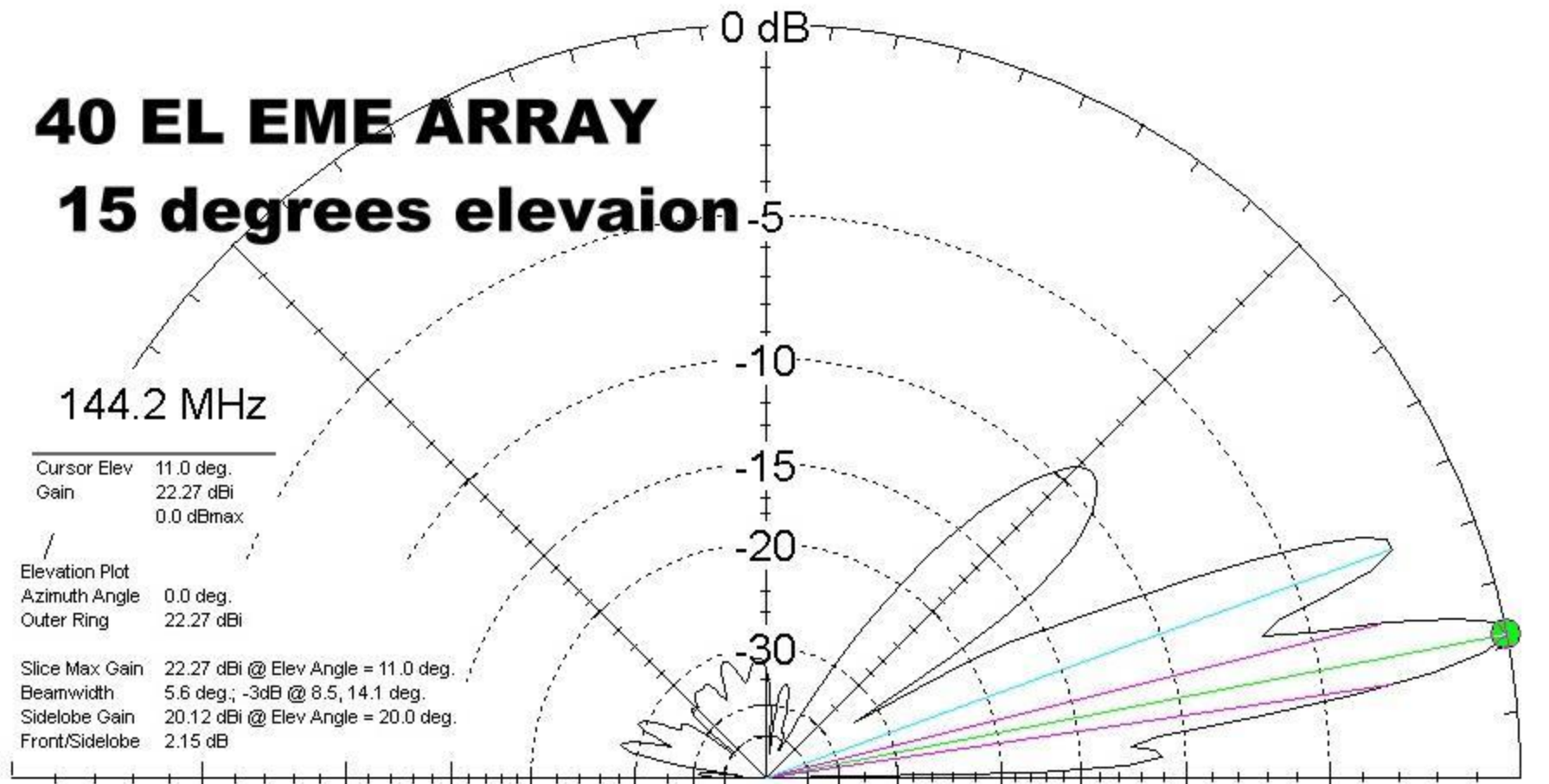
## 15 degrees elevaion

144.2 MHz

Cursor Elev 11.0 deg.  
Gain 22.27 dBi  
0.0 dBmax

Elevation Plot  
Azimuth Angle 0.0 deg.  
Outer Ring 22.27 dBi

Slice Max Gain 22.27 dBi @ Elev Angle = 11.0 deg.  
Beamwidth 5.6 deg.; -3dB @ 8.5, 14.1 deg.  
Sidelobe Gain 20.12 dBi @ Elev Angle = 20.0 deg.  
Front/Sidelobe 2.15 dB



# 40 EL EME ARRAY

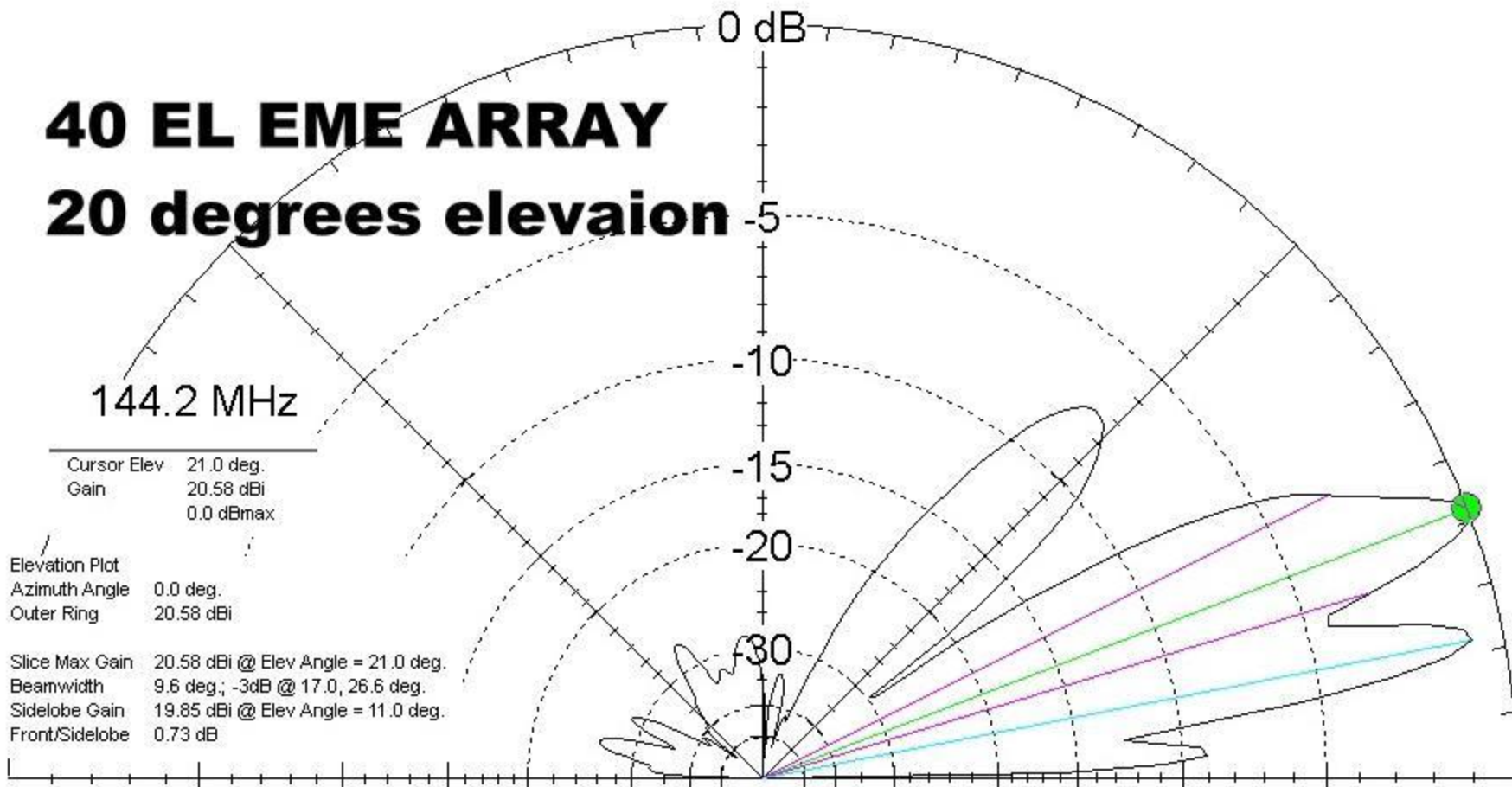
## 20 degrees elevaion

144.2 MHz

Cursor Elev 21.0 deg.  
Gain 20.58 dBi  
0.0 dBmax

Elevation Plot  
Azimuth Angle 0.0 deg.  
Outer Ring 20.58 dBi

Slice Max Gain 20.58 dBi @ Elev Angle = 21.0 deg.  
Beamwidth 9.6 deg; -3dB @ 17.0, 26.6 deg.  
Sidelobe Gain 19.85 dBi @ Elev Angle = 11.0 deg.  
Front/Sidelobe 0.73 dB



# 40 EL EME ARRAY

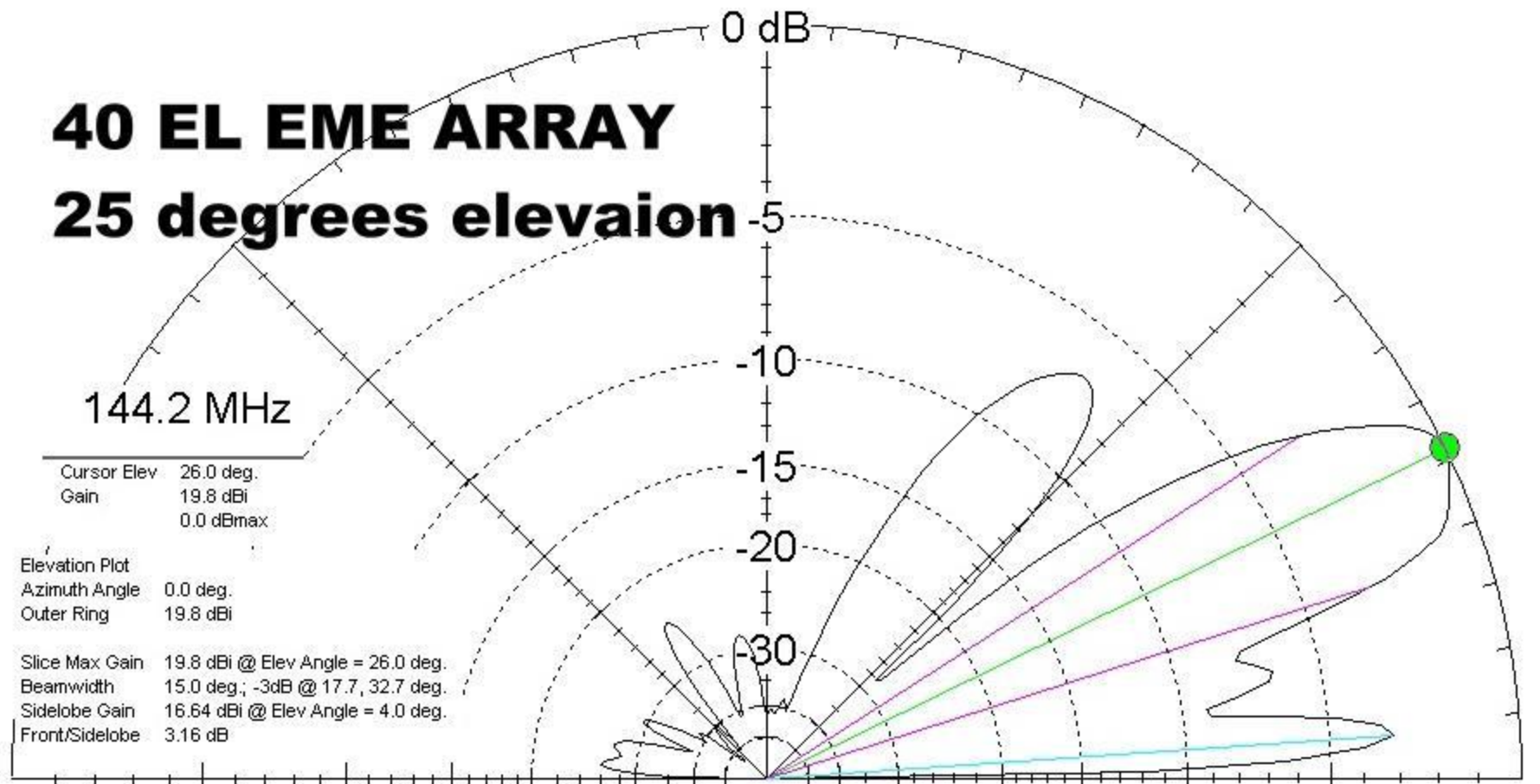
## 25 degrees elevaion

144.2 MHz

Cursor Elev 26.0 deg.  
Gain 19.8 dBi  
0.0 dBmax

Elevation Plot  
Azimuth Angle 0.0 deg.  
Outer Ring 19.8 dBi

Slice Max Gain 19.8 dBi @ Elev Angle = 26.0 deg.  
Beamwidth 15.0 deg.; -3dB @ 17.7, 32.7 deg.  
Sidelobe Gain 16.64 dBi @ Elev Angle = 4.0 deg.  
Front/Sidelobe 3.16 dB



# 40 EL EME ARRAY

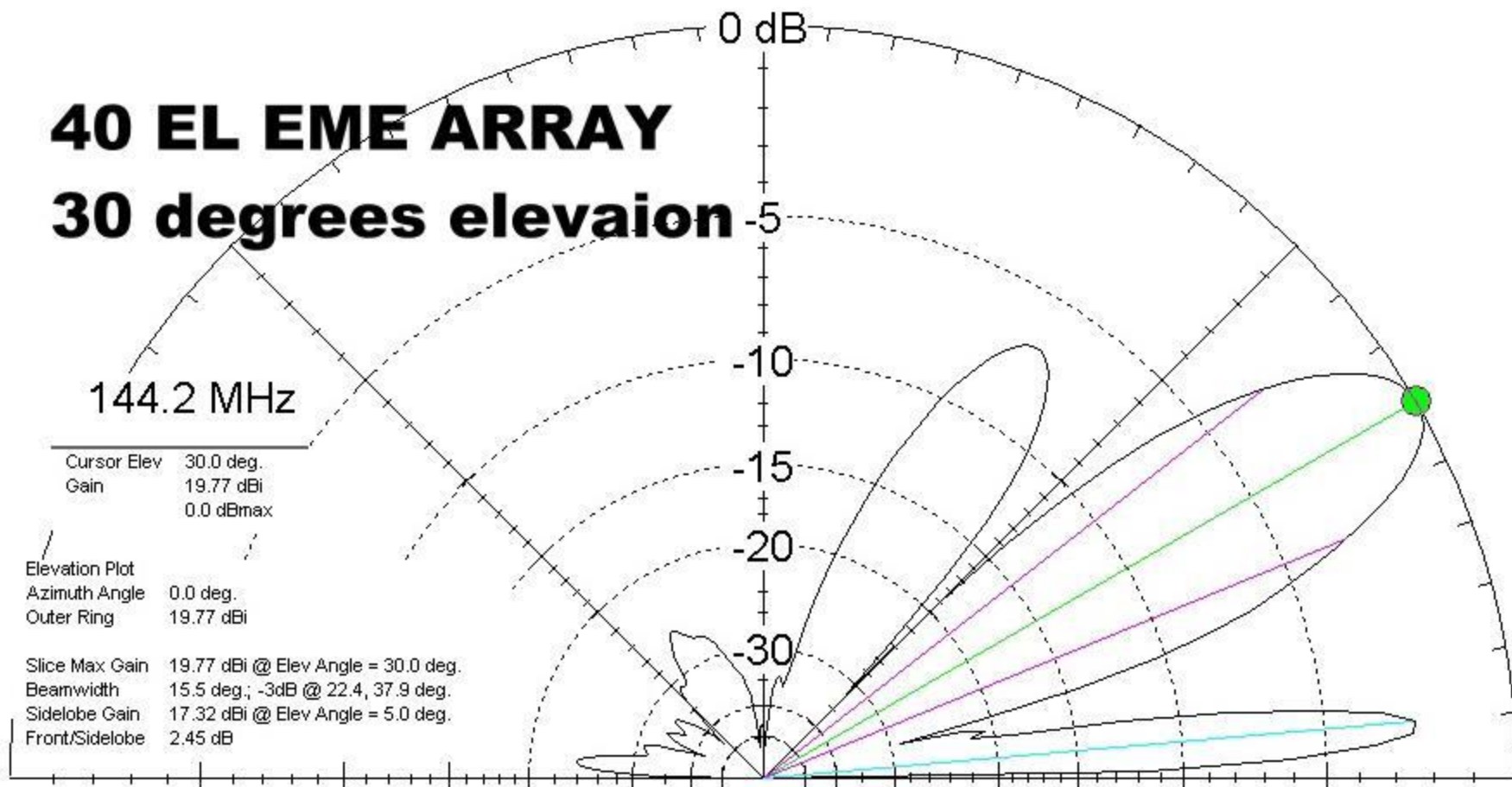
## 30 degrees elevaion

144.2 MHz

Cursor Elev 30.0 deg.  
Gain 19.77 dBi  
0.0 dBmax

Elevation Plot  
Azimuth Angle 0.0 deg.  
Outer Ring 19.77 dBi

Slice Max Gain 19.77 dBi @ Elev Angle = 30.0 deg.  
Beamwidth 15.5 deg.; -3dB @ 22.4, 37.9 deg.  
Sidelobe Gain 17.32 dBi @ Elev Angle = 5.0 deg.  
Front/Sidelobe 2.45 dB



# 40 EL EME ARRAY

## 35 degrees elevaion

144.2 MHz

Cursor Elev 35.0 deg.  
Gain 19.69 dBi  
0.0 dBmax

Elevation Plot  
Azimuth Angle 0.0 deg.  
Outer Ring 19.69 dBi

Slice Max Gain 19.69 dBi @ Elev Angle = 35.0 deg.  
Beamwidth 16.0 deg; -3dB @ 27.1, 43.1 deg.  
Sidelobe Gain 15.39 dBi @ Elev Angle = 5.0 deg.  
Front/Sidelobe 4.3 dB

0 dB

-5

-10

-15

-20

-25

-30

-35

-40

-45

-50

-55

-60

-65

-70

-75

-80

-85

-90

-95

-100

-105

-110

-115

-120

-125

-130

-135

-140

-145

-150

-155

-160

-165

-170

-175

-180

-185

-190

-195

-200

-205

-210

-215

-220

-225

-230

-235

-240

-245

-250

-255

-260

-265

-270

-275

-280

-285

-290

-295

-300

-305

-310

-315

-320

-325

-330

-335

-340

-345

-350

-355

-360

-365

-370

-375

-380

-385

-390

-395

-400

-405

-410

-415

-420

-425

-430

-435

-440

-445

-450

-455

-460

-465

-470

-475

-480

-485

-490

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-505

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-515

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-620

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-630

-635

-640

-645

-650

-655

-660

-665

-670

-675

-680

-685

-690

-695

-700

-705

-710

-715

-720

-725

-730

-735

-740

-745

-750

-755

-760

-765

-770

-775

-780

-785

-790

-795

-800

-805

-810

-815

-820

-825

-830

-835

-840

-845

-850

-855

-860

-865

-870

-875

-880

-885

-890

-895

-900

-905

-910

-915

-920

-925

-930

-935

-940

-945

-950

-955

-960

-965

-970

-975

-980

-985

-990

-995

-1000

-1005

-1010

-1015

-1020

-1025

-1030

-1035

-1040

-1045

-1050

-1055

-1060

-1065

-1070

-1075

-1080

-1085

-1090

-1095

-1100

-1105

-1110

-1115

-1120

-1125

-1130

-1135

-1140

-1145

-1150

-1155

-1160

-1165

-1170

-1175

-1180

-1185

-1190

-1195

-1200

-1205

-1210

-1215

-1220

-1225

-1230

-1235

-1240

-1245

-1250

-1255

-1260

-1265

-1270

-1275

-1280

-1285

-1290

-1295

-1300

-1305

-1310

-1315

-1320

-1325

-1330

-1335

-1340

-1345

-1350

-1355

-1360

-1365

-1370

-1375

-1380

-1385

-1390

-1395

-1400

-1405

-1410

-1415

-1420

-1425

-1430

-1435

-1440

-1445

-1450

-1455

-1460

-1465

-1470

-1475

-1480

-1485

-1490

-1495

-1500

-1505

-1510

-1515

-1520

-1525

-1530

-1535

-1540

# 40 EL EME ARRAY

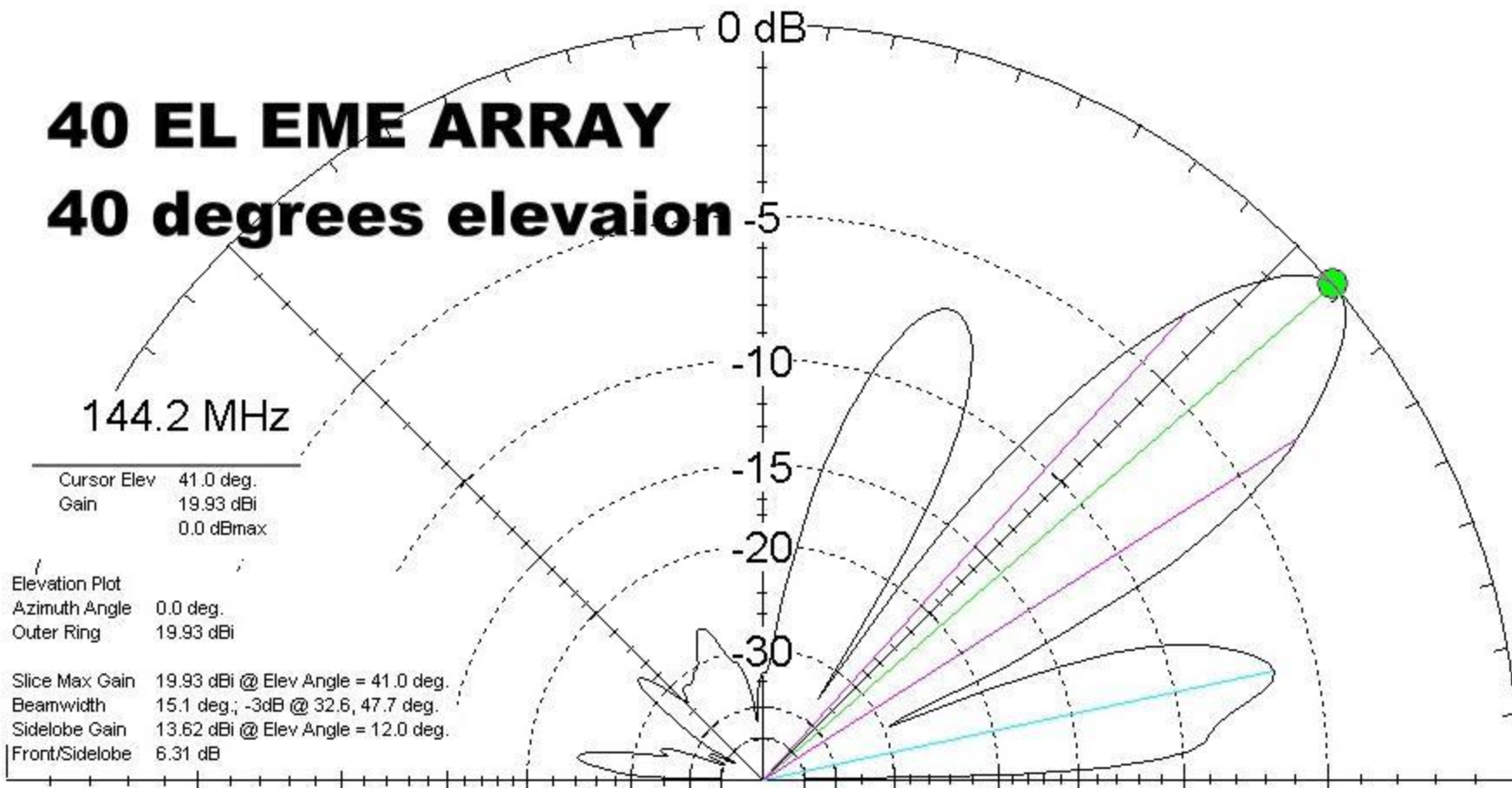
## 40 degrees elevaion

144.2 MHz

Cursor Elev 41.0 deg.  
Gain 19.93 dBi  
0.0 dBmax

Elevation Plot  
Azimuth Angle 0.0 deg.  
Outer Ring 19.93 dBi

Slice Max Gain 19.93 dBi @ Elev Angle = 41.0 deg.  
Beamwidth 15.1 deg.; -3dB @ 32.6, 47.7 deg.  
Sidelobe Gain 13.62 dBi @ Elev Angle = 12.0 deg.  
Front/Sidelobe 6.31 dB



# 40 EL EME ARRAY

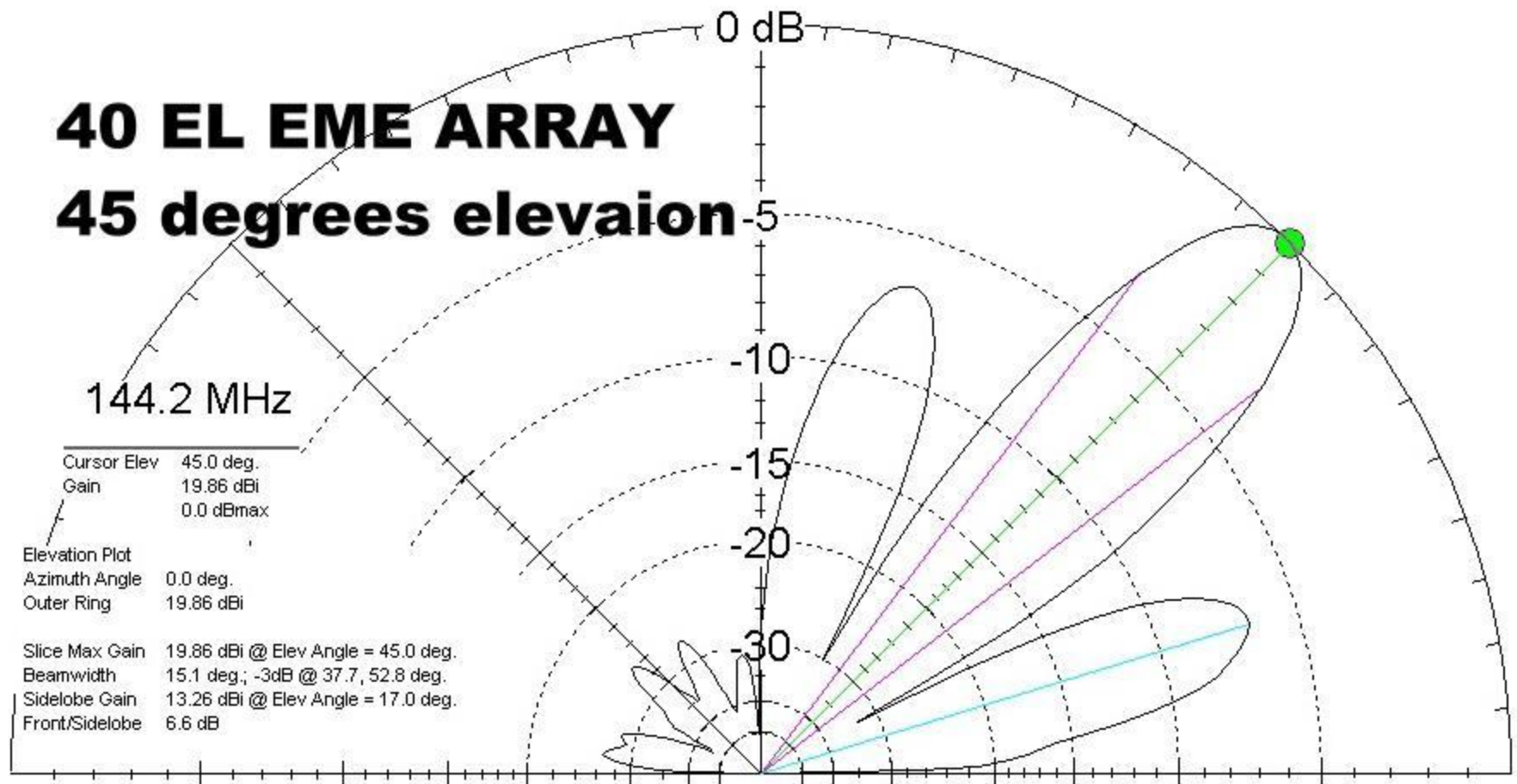
## 45 degrees elevaion

144.2 MHz

Cursor Elev 45.0 deg.  
Gain 19.86 dBi  
0.0 dBmax

Elevation Plot  
Azimuth Angle 0.0 deg.  
Outer Ring 19.86 dBi

Slice Max Gain 19.86 dBi @ Elev Angle = 45.0 deg.  
Beamwidth 15.1 deg.; -3dB @ 37.7, 52.8 deg.  
Sidelobe Gain 13.26 dBi @ Elev Angle = 17.0 deg.  
Front/Sidelobe 6.6 dB



# 40 EL EME ARRAY

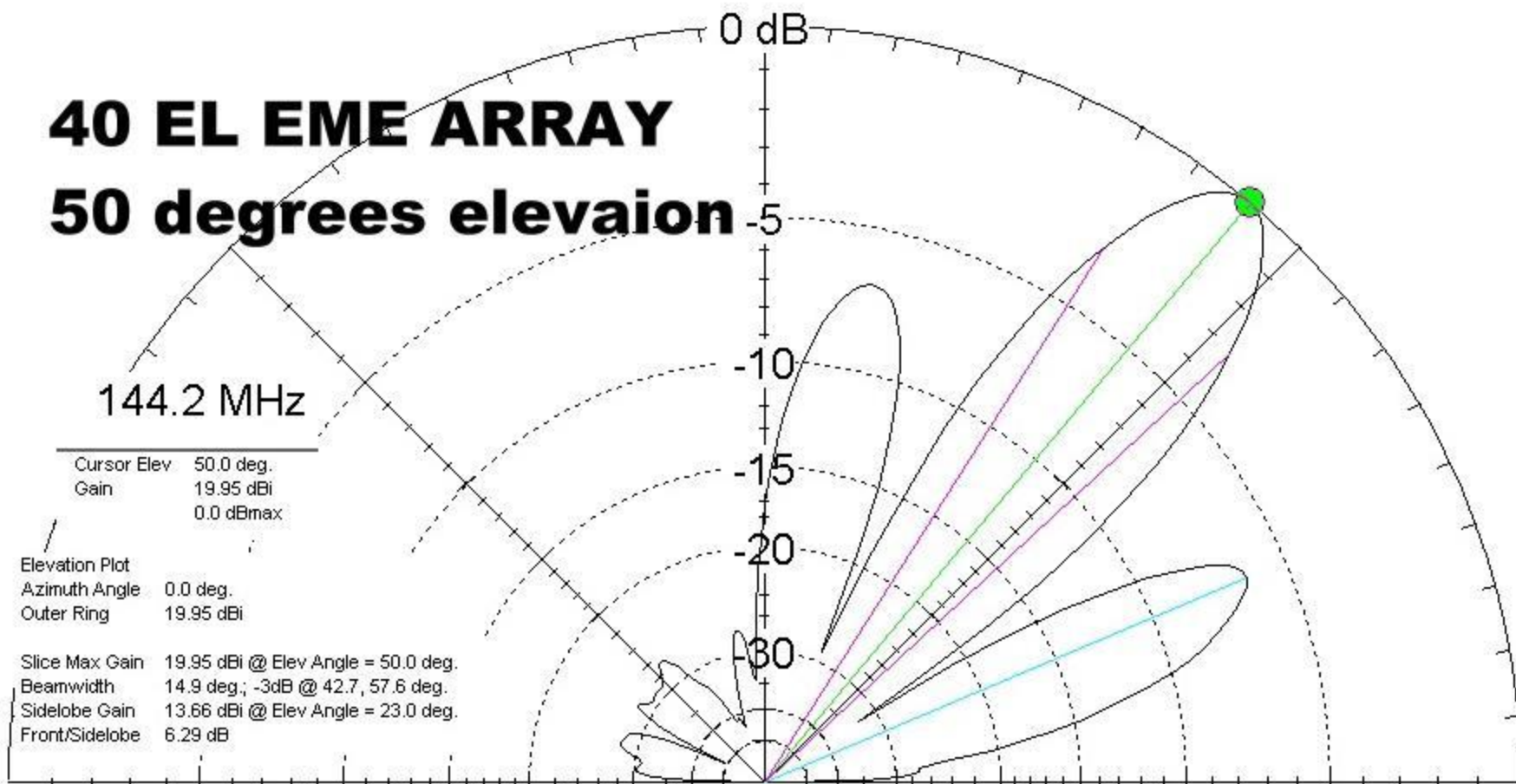
## 50 degrees elevaion

144.2 MHz

Cursor Elev 50.0 deg.  
Gain 19.95 dBi  
0.0 dBmax

Elevation Plot  
Azimuth Angle 0.0 deg.  
Outer Ring 19.95 dBi

Slice Max Gain 19.95 dBi @ Elev Angle = 50.0 deg.  
Beamwidth 14.9 deg.; -3dB @ 42.7, 57.6 deg.  
Sidelobe Gain 13.66 dBi @ Elev Angle = 23.0 deg.  
Front/Sidelobe 6.29 dB



# 40 EL EME ARRAY

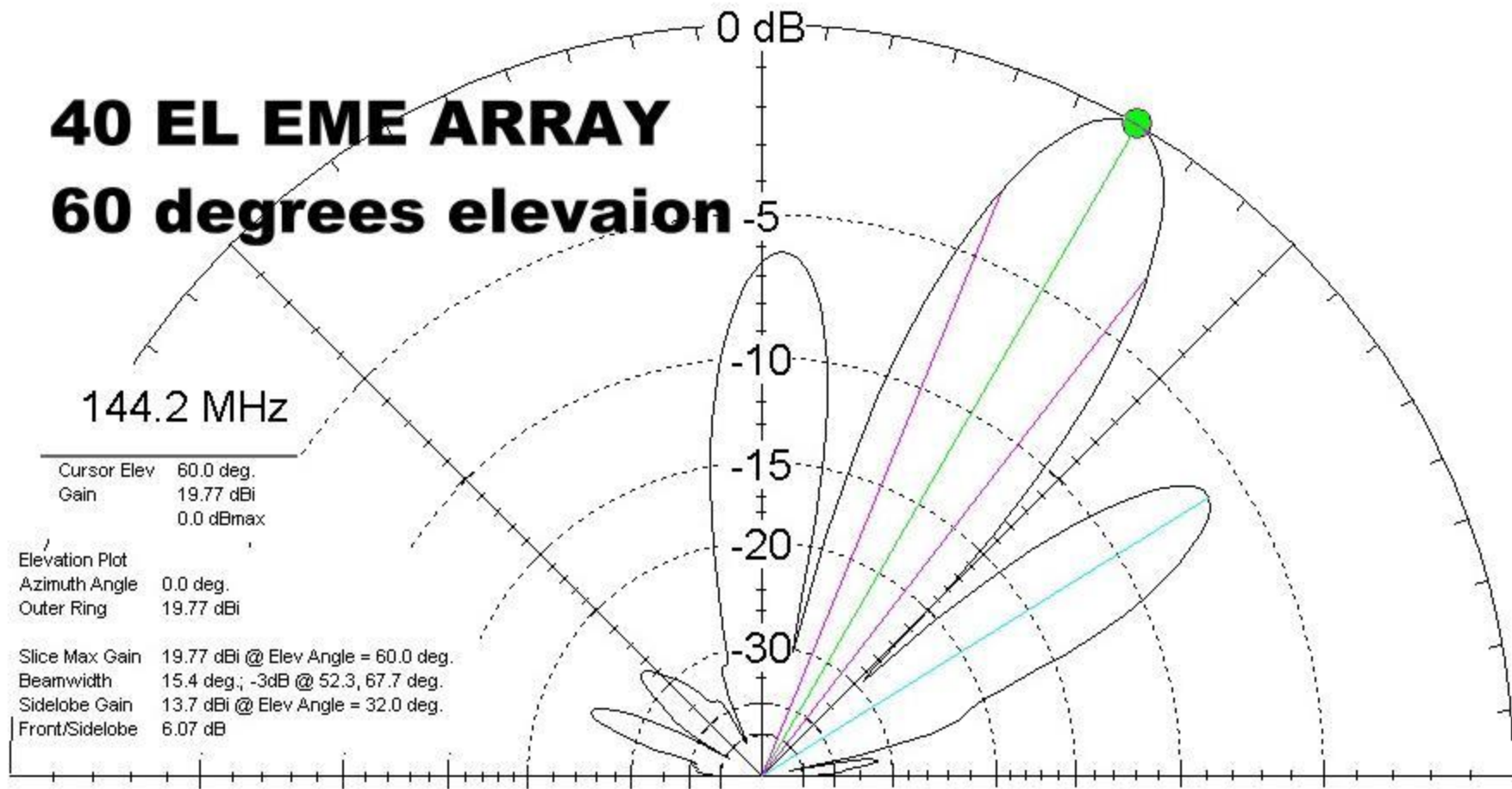
## 60 degrees elevaion

144.2 MHz

Cursor Elev 60.0 deg.  
Gain 19.77 dBi  
0.0 dBmax

Elevation Plot  
Azimuth Angle 0.0 deg.  
Outer Ring 19.77 dBi

Slice Max Gain 19.77 dBi @ Elev Angle = 60.0 deg.  
Beamwidth 15.4 deg.; -3dB @ 52.3, 67.7 deg.  
Sidelobe Gain 13.7 dBi @ Elev Angle = 32.0 deg.  
Front/Sidelobe 6.07 dB



# 40 EL EME ARRAY

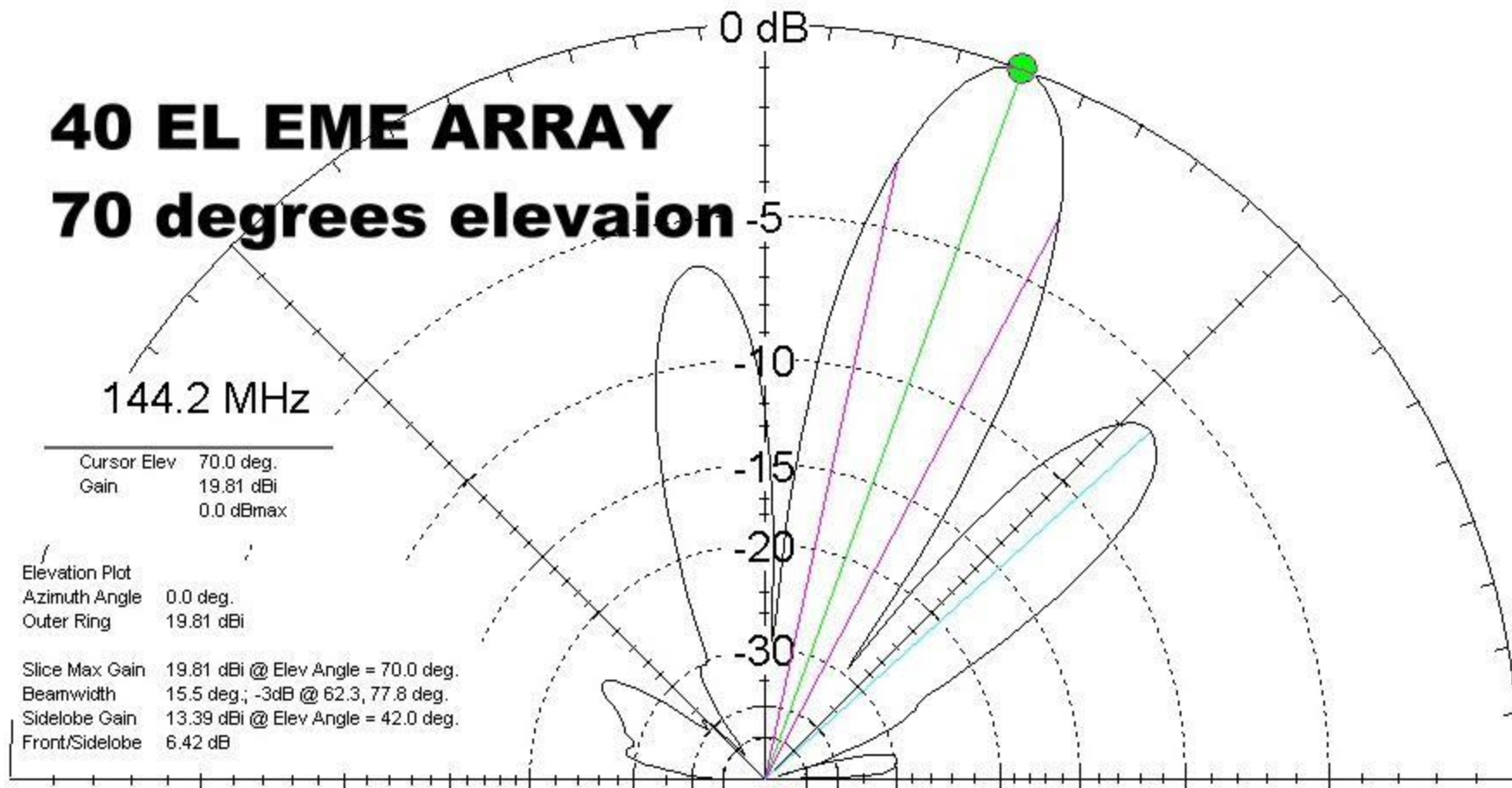
## 70 degrees elevaion

144.2 MHz

Cursor Elev 70.0 deg.  
Gain 19.81 dBi  
0.0 dBmax

Elevation Plot  
Azimuth Angle 0.0 deg.  
Outer Ring 19.81 dBi

Slice Max Gain 19.81 dBi @ Elev Angle = 70.0 deg.  
Beamwidth 15.5 deg.; -3dB @ 62.3, 77.8 deg.  
Sidelobe Gain 13.39 dBi @ Elev Angle = 42.0 deg.  
Front/Sidelobe 6.42 dB



# 40 EL EME ARRAY

## 80 degrees elevaion

144.2 MHz

Cursor Elev 80.0 deg.  
Gain 19.72 dBi  
0.0 dBmax

Elevation Plot  
Azimuth Angle 0.0 deg.  
Outer Ring 19.72 dBi

Slice Max Gain 19.72 dBi @ Elev Angle = 80.0 deg.  
Beamwidth 15.6 deg.; -3dB @ 72.0, 87.6 deg.  
Sidelobe Gain 13.15 dBi @ Elev Angle = 52.0 deg.  
Front/Sidelobe 6.57 dB

0 dB

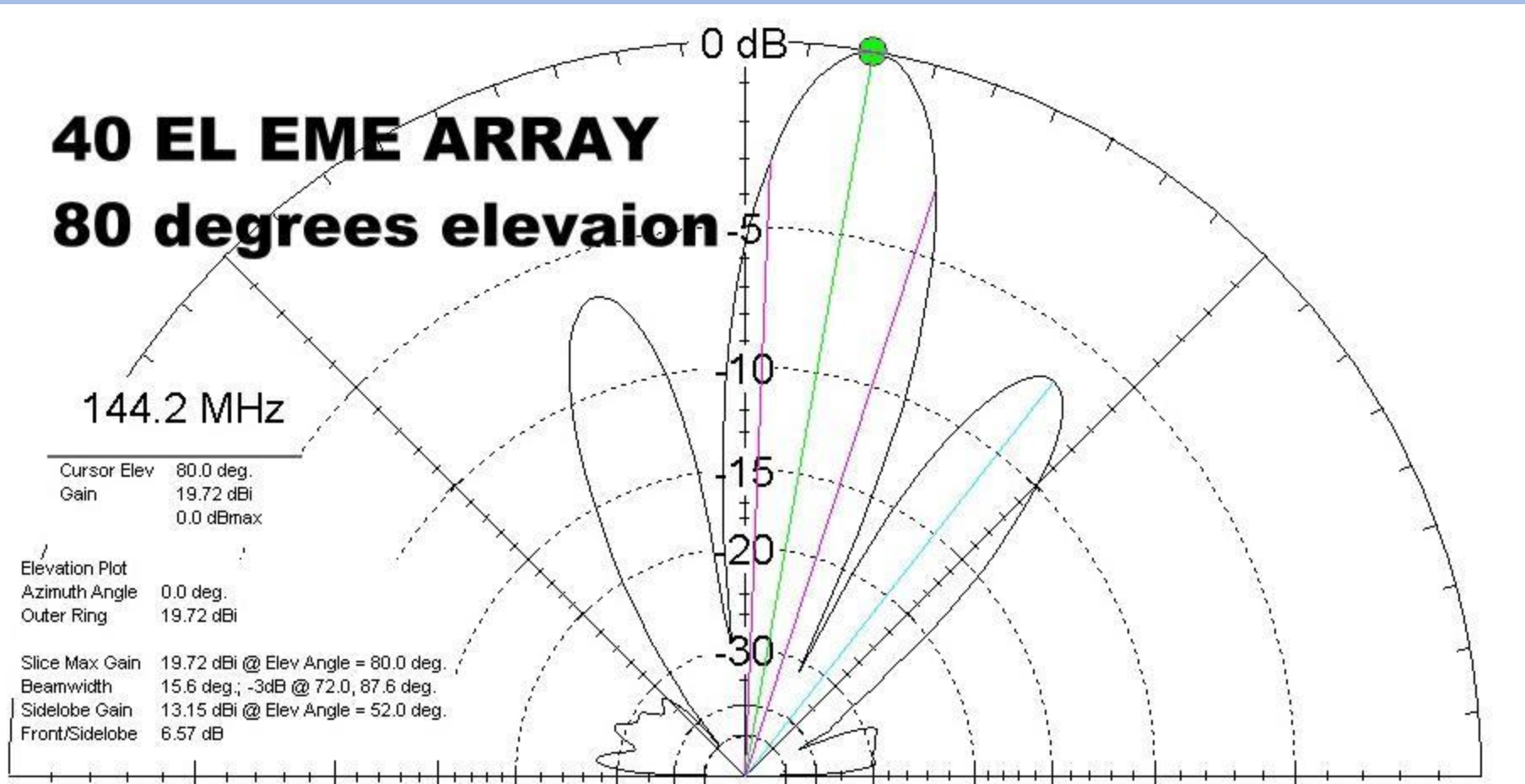
-5

-10

-15

-20

-30



**So, what have we learned from all this?**

- \* A Horizontally polarized Yagi close to the ground has ~4.7 dB extra gain due to the ground proximity (It can have as much as 6 dB over perfect ground)**
- \* As we increase the height above ground we get an increased number of lobes but they get narrower.**
- As we raise the antenna from  $\frac{1}{4}$  WL, we also get more gain due to ground gain, to a point.**
- \* As we increase the height above ground we approach the free space pattern of the antenna with lowering gain.**
- These trends exist for ALL directional antennas over ground as we saw comparing 2, 6 and 10 meter arrays & a 40 M Dipole.**
- \* Ground gain is reduced 1-3 dB for a vertically polarized antenna vs. a horizontal antenna**

**Now, How do we use this Information?**

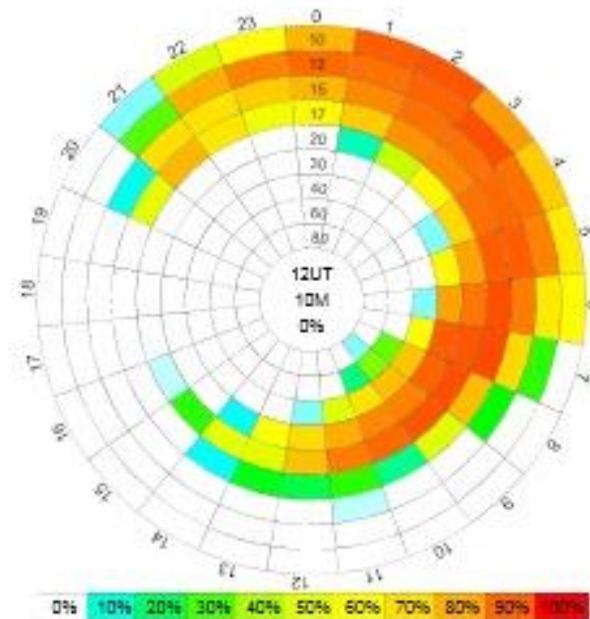
**We use it to predict where our signal will go at any given time on any given band.**

**VOACAP knows how big and how high antennas are at both ends and it calculates the best time of day for the power you use for the path you want.**

# VOACAP Propagation Prediction Program Can be Purchased or Used Online at:

 <http://www.voacap.com/prediction.html>

## VOACAP Online



TX to RX: 15607 km, 9698 mi, 241 \* Year: 2015 Month: May This

### Propagation Params

Es:  Model:   
 SSN:  Min.TQA:

### Today's Sunrise/Sunset Times (UTC)

	Transmitter		Receiver	
	Rise	Set	Rise	Set
GND	10:39	23:58	21:10	07:24
D	10:11	00:26	20:39	07:55
F	09:34	01:03	20:00	08:35

### Transmitter Site

QTH:   
 Name:    
 Latitude:  [-90..90]  
 Longitude:  [-180..180]  
 TX antenna:   
 TX power:   
 TX mode:   
 Special:    
 Current point:

### Receiver Site

QTH:   
 Name:    
 Latitude:  [-90..90]  
 Longitude:  [-180..180]  
 RX antenna:

The circular chart above shows predictions for all HF amateur radio bands. How

TX to RX:  km,  mi,  ° Year:

Propagation Params

Es:  Model:   
SSN:  Min.TOA:  °

Today's Sunrise/Sunset Times (UTC)

	Transmitter		Receiver	
	Rise	Set	Rise	Set
GND	<input type="text" value="11:35"/>	<input type="text" value="23:16"/>	<input type="text" value="19:46"/>	<input type="text" value="08:31"/>
D	<input type="text" value="11:08"/>	<input type="text" value="23:43"/>	<input type="text" value="19:16"/>	<input type="text" value="09:00"/>
F	<input type="text" value="10:33"/>	<input type="text" value="00:18"/>	<input type="text" value="18:36"/>	<input type="text" value="09:40"/>

TX to RX:  km,  mi,  ° Year:  Month:

Transmitter Site

QTH:

Name:

Latitude:  [-90..90]

Longitude:  [-180..180]

TX antenna:

TX power:

TX mode:

Specials:

Current point:

Receiver Site

QTH:

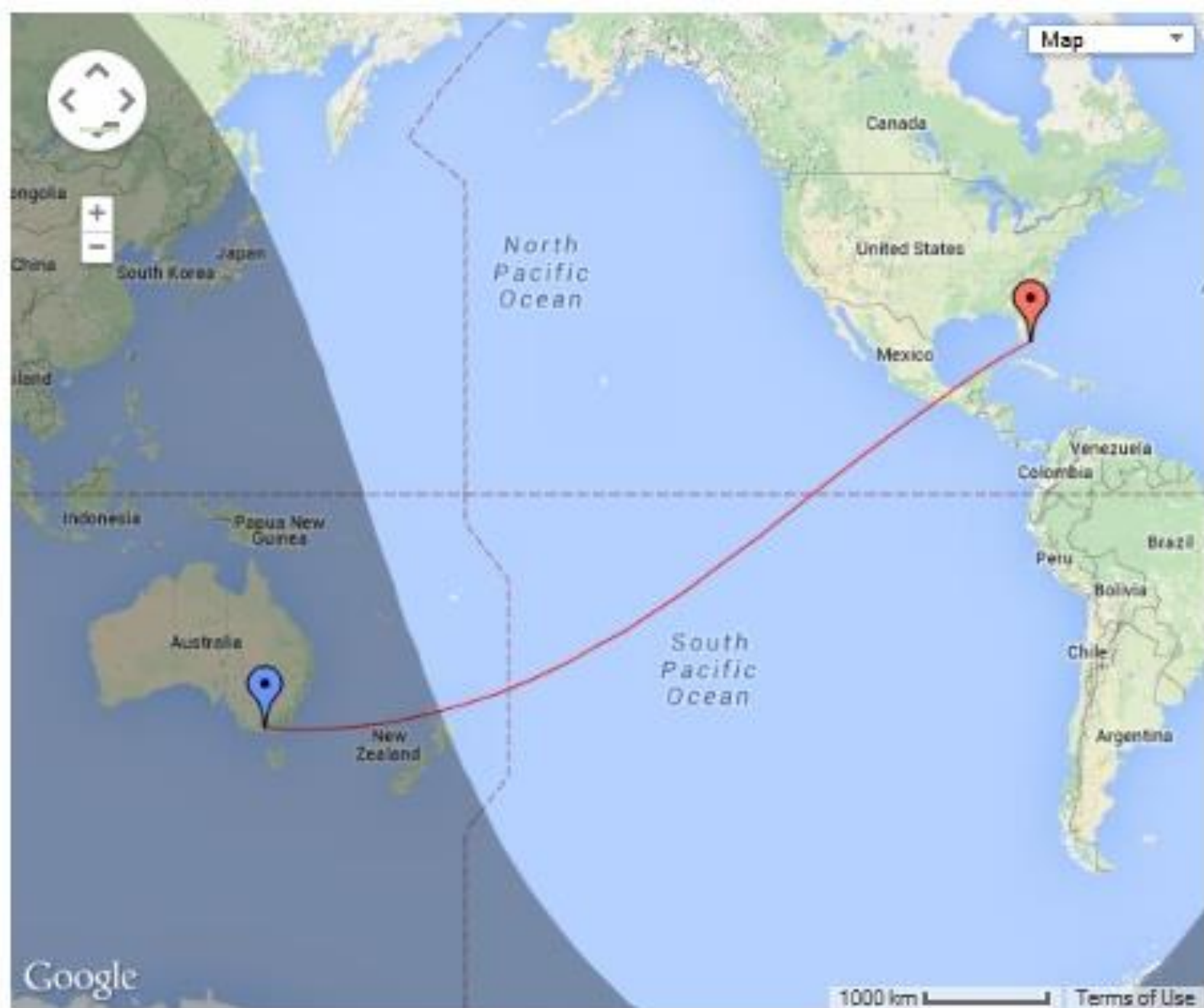
Name:

Latitude:  [-90..90]

Longitude:  [-180..180]

RX antenna:

The circular chart above shows predictions for all HF amateur bands. Hover the mouse over the chart for details. For predictions with more frequency coverage, click the "Run prediction!"



TX to RX:  km,  mi,  ° Year:  Month:



# Thank you for your attention.

## Any Questions?



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10 BAND DXCC - 5 BAND WAZ - NO. 1 HONOR ROLL

CFM QSO with:

Date	UTC	MHz	2-Way	RS(T)

PSE QSL TKS  73, \_\_\_\_\_



EME Station: 1.5 KW to 4 x 20 XP M-2 Antennas

Your best EME S/N report: \_\_\_\_\_

HF Station: Icom 7600 Icom 7100 Icom 7000  
(HF) AMP Supply LK-800 (5 M) HEATHKIT SB-200

QSL FRONT: 1/4 WAVE SHUNT FED TOWER - 160 M.  
STEPPER DB-36 1/2 70 FT. 80 M Inv. Vee 90 Ft.  
WALLER FLAG LOOP 3 80 FT. H & V POLARIZATION  
6 EL HY GAIN 6 M YAGI - MAGNETIC LOOP FOR 160