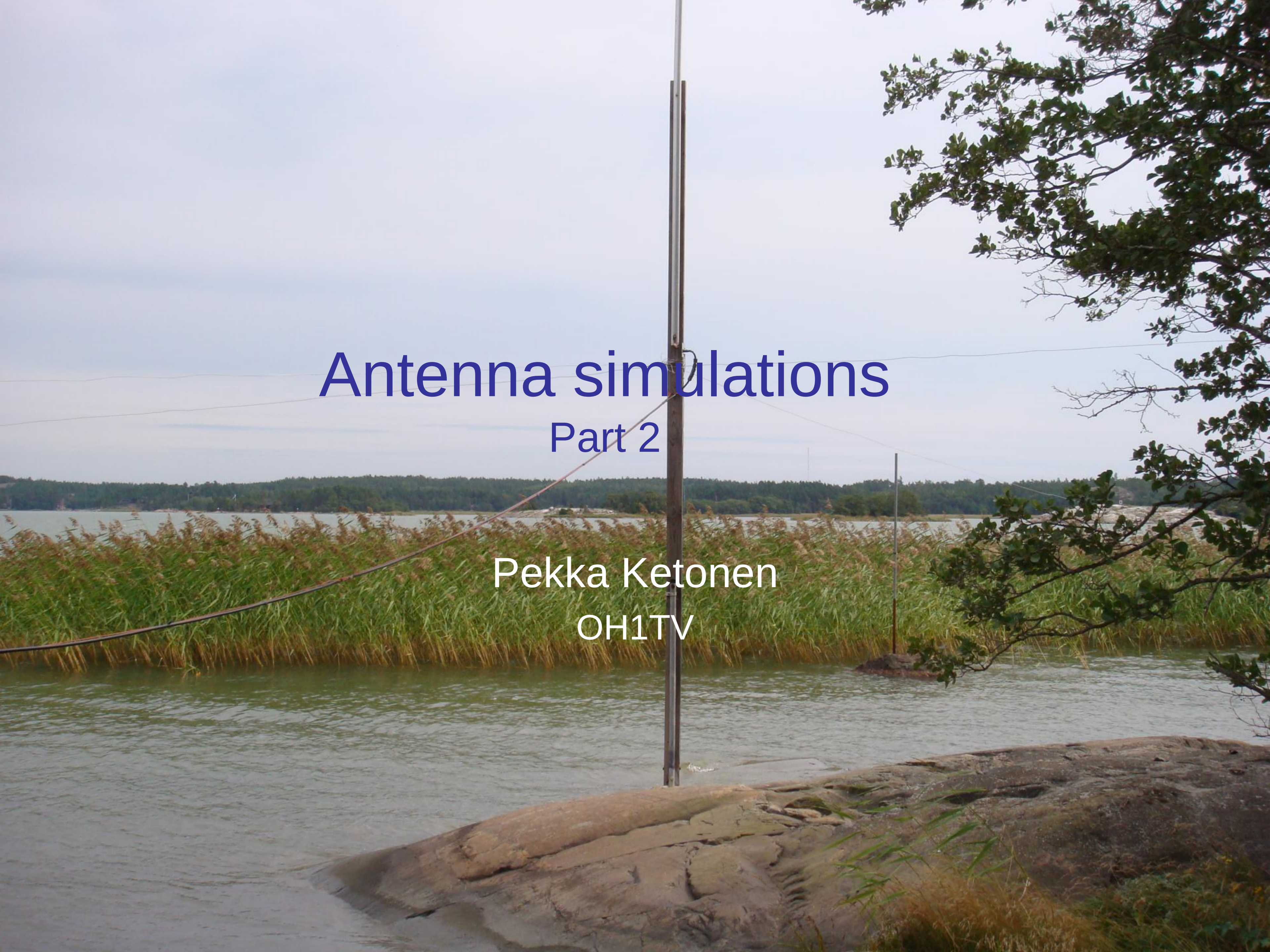
Antenna simulations

Part 2

Pekka Ketonen

OH1TV



Outline

Part 1

- Some principles in antenna design
  - typical steps in design process
- Opposite Voltage Feed
  - 2 phased verticals on 80m
  - 2 over 2 on 40m
  - Quad improved

Part 2

- Influence of location on antenna performance
  - Lakeside
  - Seaside
  - Steep coast, cliff
  - Hilltop
- Stacking

Content

1. Influence of surrounding water on vertical antenna
2. Influence of surrounding water on horizontal antenna
3. Influence of steep coast (cliff) on horizontal antenna
4. Hill top antennas
5. Stacking considerations
6. Mutual coupling of different bands

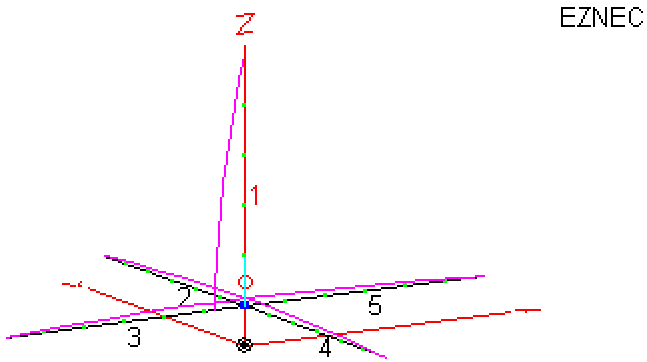
Soil conductivity and dielectric constant

Earth Type	Conductivity Sigma (Mhos/m)	Permittivity Epsilon
Poor	0.001	4.0 - 5.0
Moderate	0.003	4.0
Average	**0.005 - 0.01**	**10.0 - 15.0**
Good	0.01 - 0.02	4.0 - 30.0
Dry, sandy, flat (typical of coastal land)	0.002	10.0
Pastoral Hills, rich soil	0.003 - 0.01	14.0 - 20.0
Pastoral medium hils and forestation	0.004 - 0.006	13.0
Fertile land	0.002	10.0
Rich agricultural land (low hills)	0.01	15.0
Rocky land, steep hills	0.002	10.0 - 15.0
Marshy land, densely wooded	0.0075	12.0
Marshy, forested, flat	0.008	12.0
Mountainous/hilly (to about 1000 m)	0.001	5.0
Highly moist ground	0.005 - 0.02	30.0
City Industrial area of average attenuation	0.001	5.0
City industrial area of maximal attenuation	0.0004	3.0
City industrial area	0.0001	3.0
Fresh water	**0.002 - 0.01**	**80.0 - 81.0**
Fresh water at 10.0 deg C (At 100 MHz)	0.001 - 0.01	84.0
Fresh water at 20.0 deg C (At 100 MHz)	0.001 - 0.01	80.0
Sea water	**4.0 - 5.0**	**80.0 - 81.0**
Sea water at 10.0 deg C (to 1.0 GHz)	4.0 - 5.0	80.0
Sea water at 20.0 deg C (to 1.0 GHz)	4.0 - 5.0	73.0
Sea ice	0.001	4.0
Polar ice	0.00025	3.0
Polar Ice Cap	0.0001	1.0
Arctic land	0.0005	3.0

1. Influence of nearby WATER on vertical antenna

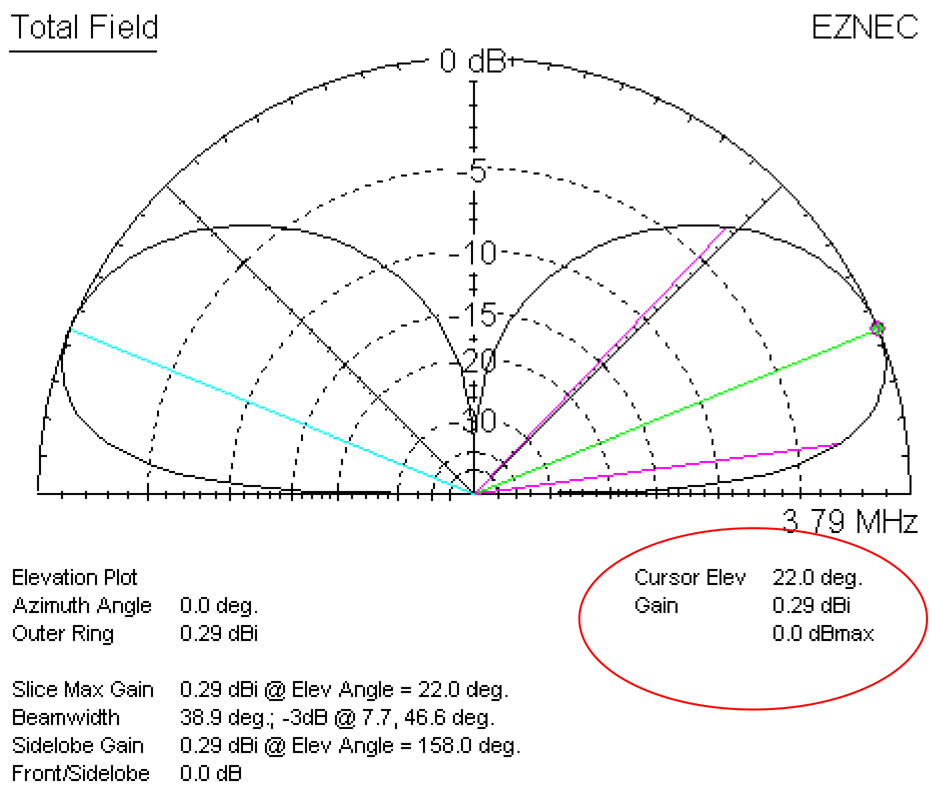
80m vertical, average flat ground

4 elevated radials up 3m



Average ground

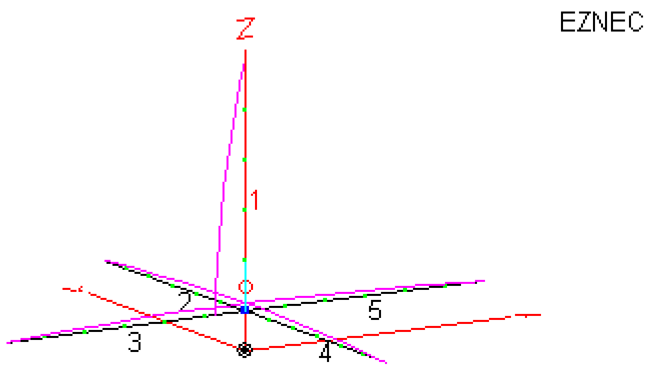
5mS, Є=13

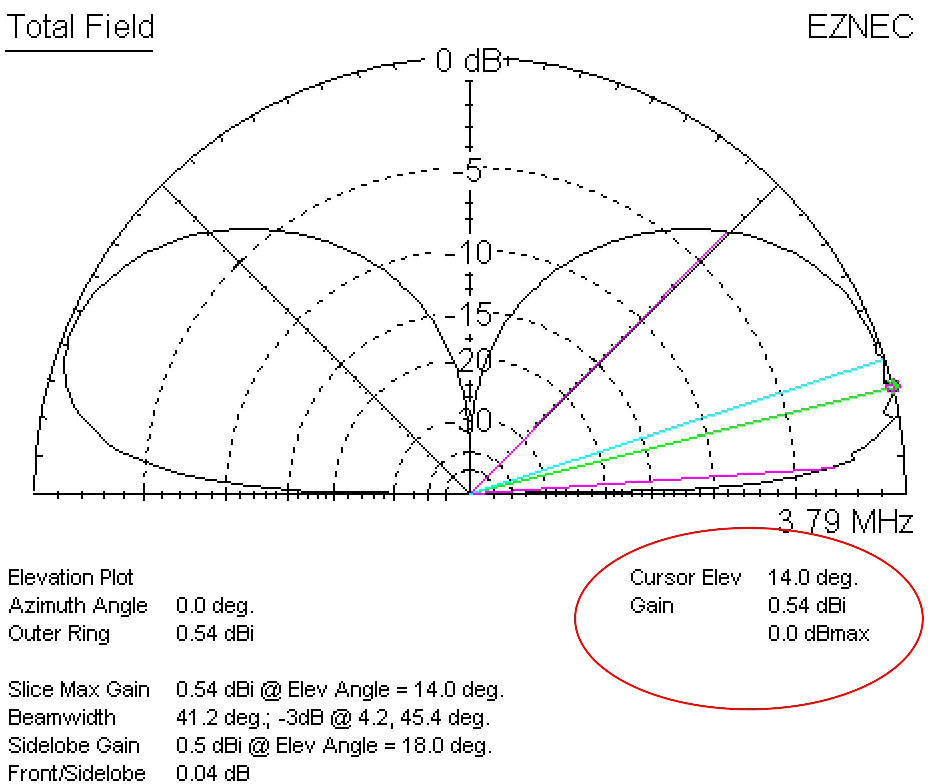


Theoretical maximum gain 5.15dBi

Vertical, fresh water 50m away, 3m down

4 elevated radials up 3m





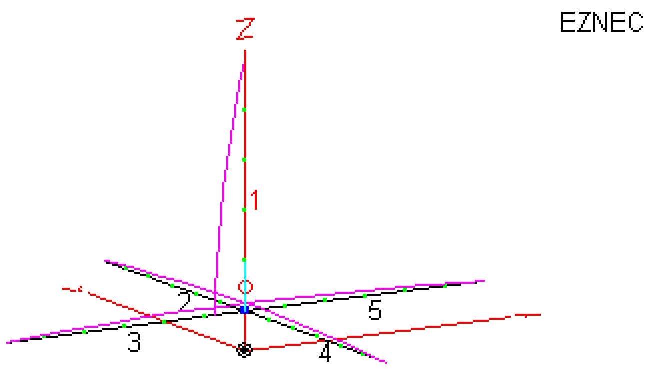
X<50m, Z=0, Average ground
5mS, Є=13

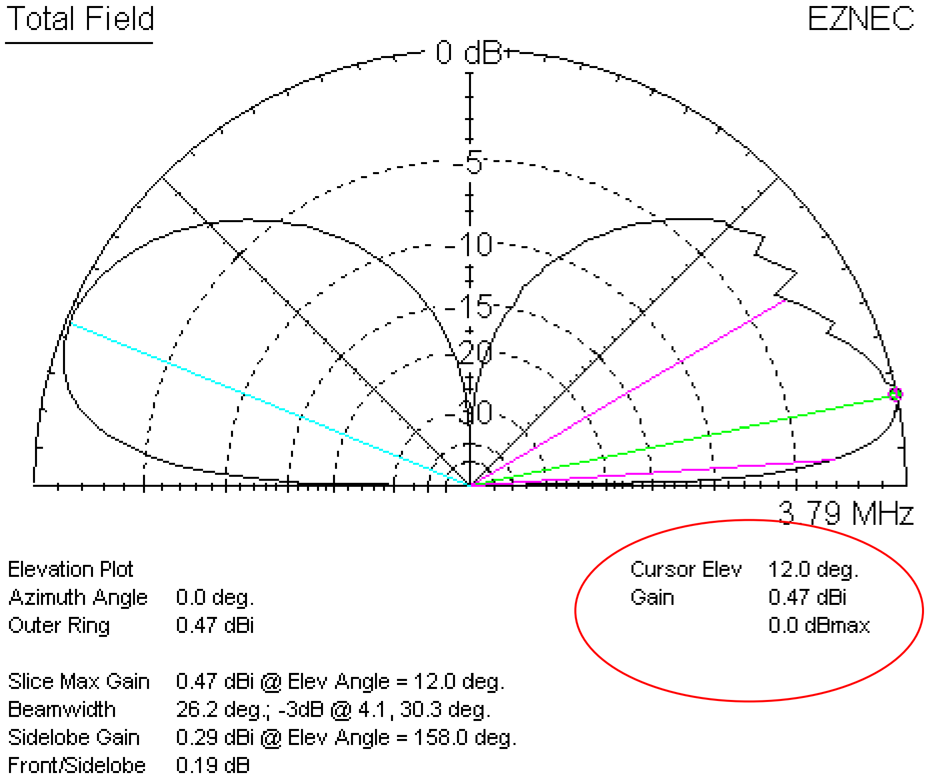
X>50m, Z=-3m, Fresh water
5mS, Є=80

0.25dB fresh water gain
8deg lowered TOA

Vertical, fresh water 20m away, 3m down

4 elevated radials up 3m





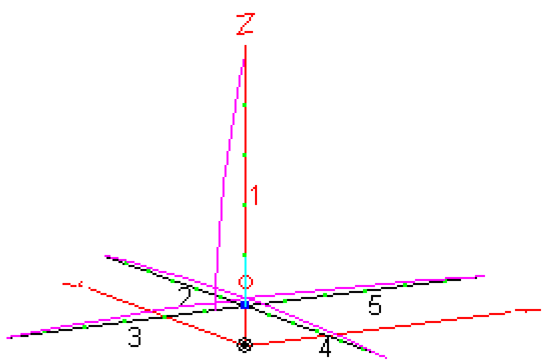
X<20m, Z=0, Average ground
5mS, Є=13

X>20m, Z=-3m, Fresh water
5mS, Є=80

0.18dB fresh water gain
10deg lowered TOA

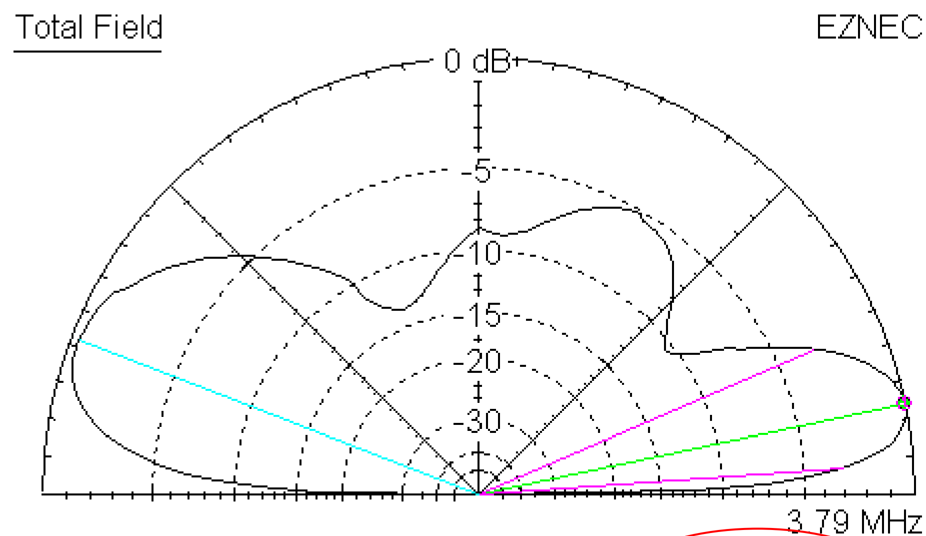
Vertical, fresh water 0m away, 3m down

4 elevated radials up 3m



X<0m, Z=0, Average ground
5mS, Є=13

X>0m, Z=-3m, Fresh water
5mS, Є=80



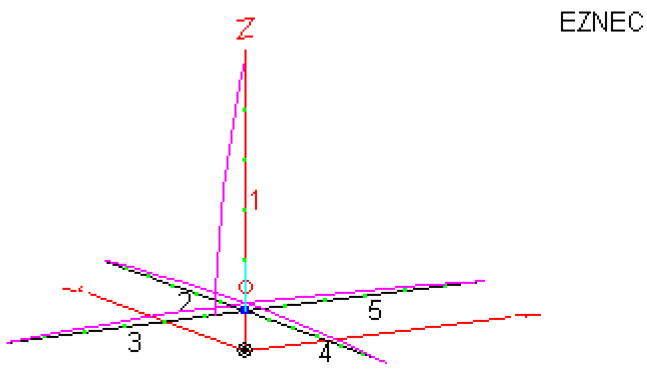
Elevation Plot	
Azimuth Angle	0.0 deg.
Outer Ring	0.5 dBi
Slice Max Gain	0.5 dBi @ Elev Angle = 12.0 deg.
Beamwidth	19.1 deg.; -3dB @ 4.1, 23.2 deg.
Sidelobe Gain	0.15 dBi @ Elev Angle = 159.0 deg.
Front/Sidelobe	0.35 dB

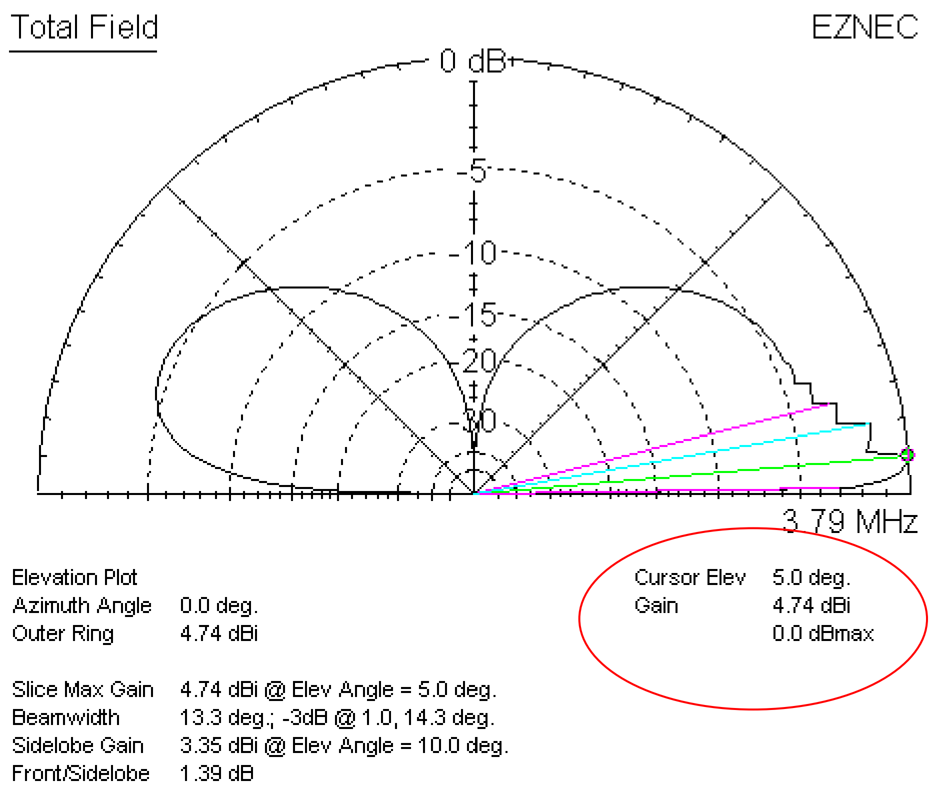
Cursor Elev	12.0 deg.
Gain	0.5 dBi
	0.0 dBmax

0.21dB fresh water gain
10deg lowered TOA

Vertical, sea water 50m away, 3m down

4 elevated radials up 3m





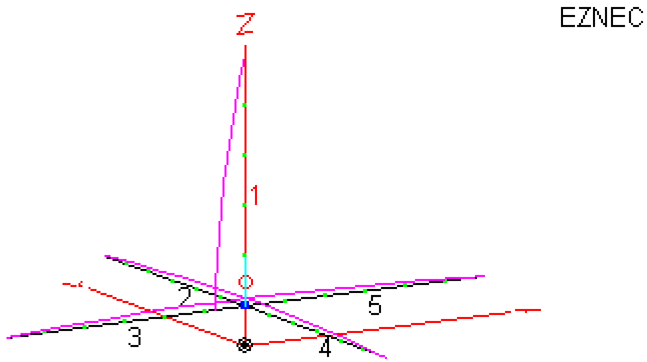
X<50m, Z=0, Average ground
5mS, Є=13

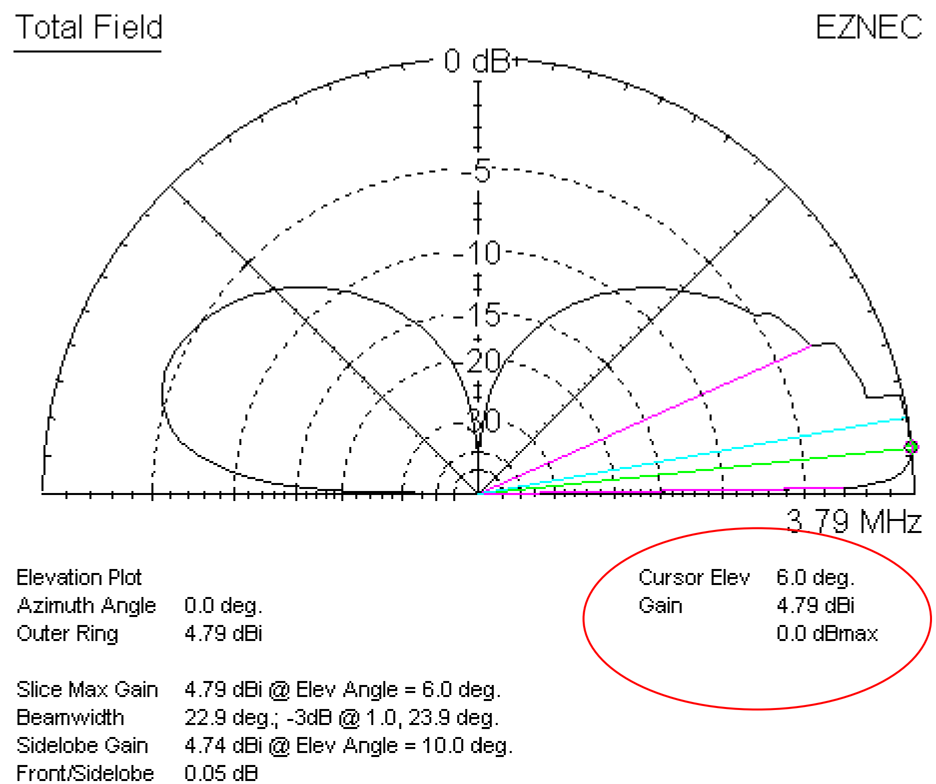
X>50m, Z=-3m, Sea water
2S, Є=80 (Baltic Sea)

4.45dB sea water gain
17 deg lowered TOA

Vertical, sea water 20m away, 3m down

4 elevated radials up 3m





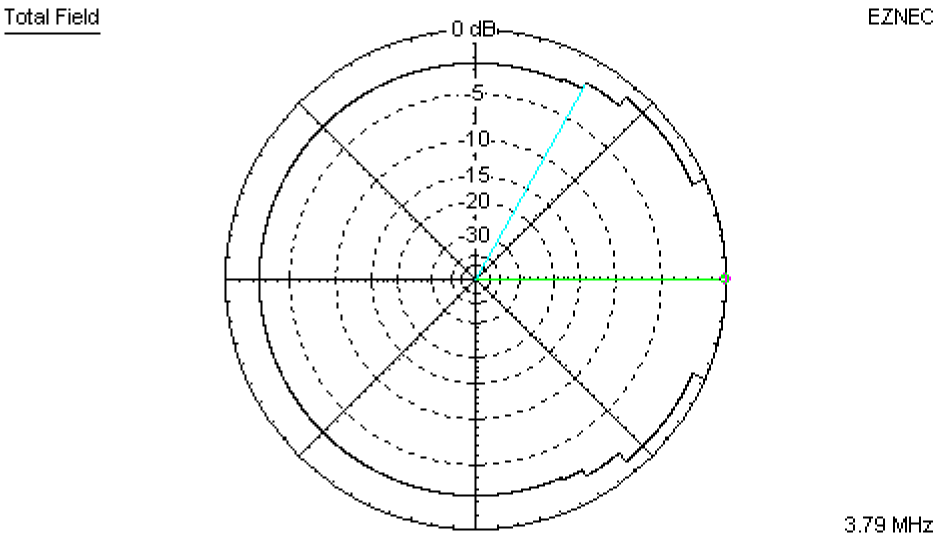
X<20m, Z=0, Average ground
5mS, Є=13

X>20m, Z=-3m, Sea water
2S, Є=80 (Baltic Sea)

4.50dB sea water gain
16deg lowered TOA

Vertical, sea water 20m away, 3m down

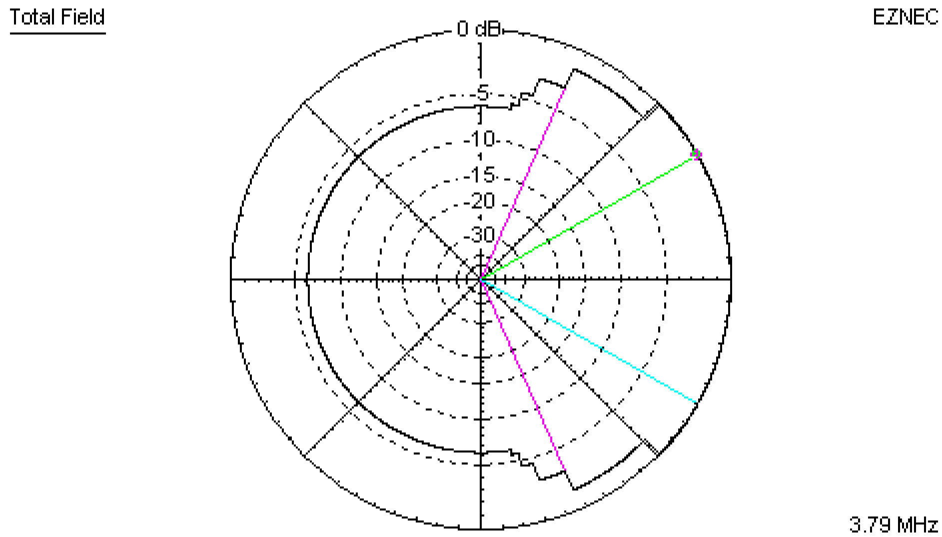
4 elevated radials up 3m
Elevation angles 22 and 10 deg



Azimuth Plot
Elevation Angle 22.0 deg.
Outer Ring 2.79 dBi

Cursor Az 0.0 deg.
Gain 2.79 dBi
0.0 dBmax

Slice Max Gain 2.79 dBi @ Az Angle = 0.0 deg.
Front/Back 2.5 dB
Beamwidth ?
Sidelobe Gain 1.01 dBi @ Az Angle = 60.8 deg.
Front/Sidelobe 1.78 dB



Azimuth Plot
Elevation Angle 10.0 deg.
Outer Ring 4.77 dBi

Cursor Az 29.9 deg.
Gain 4.77 dBi
0.0 dBmax

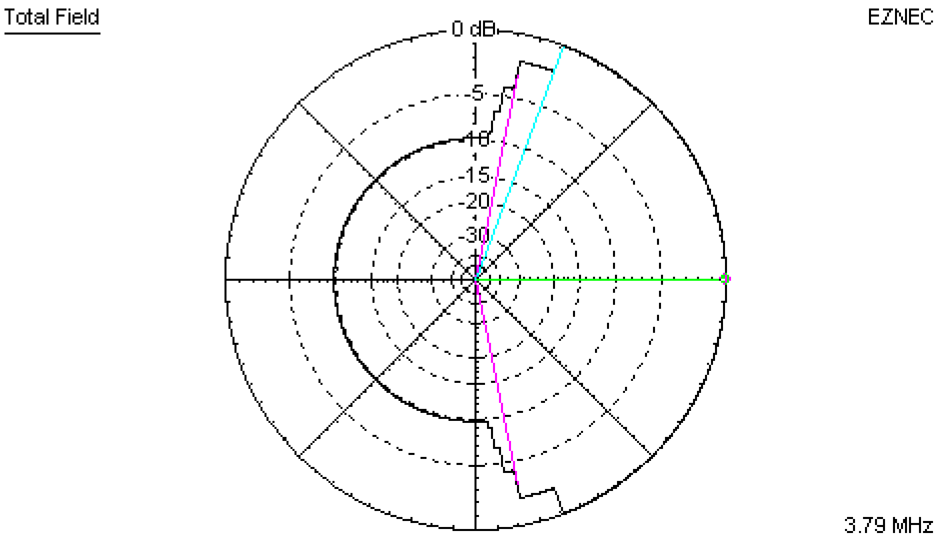
Slice Max Gain 4.77 dBi @ Az Angle = 29.9 deg.
Front/Back 6.32 dB
Beamwidth 133.0 deg.; -3dB @ 293.5, 66.5 deg.
Sidelobe Gain 4.77 dBi @ Az Angle = 330.0 deg.
Front/Sidelobe 0.0 dB

2.5dB sea water gain on 22deg

6dB sea water gain on 10deg

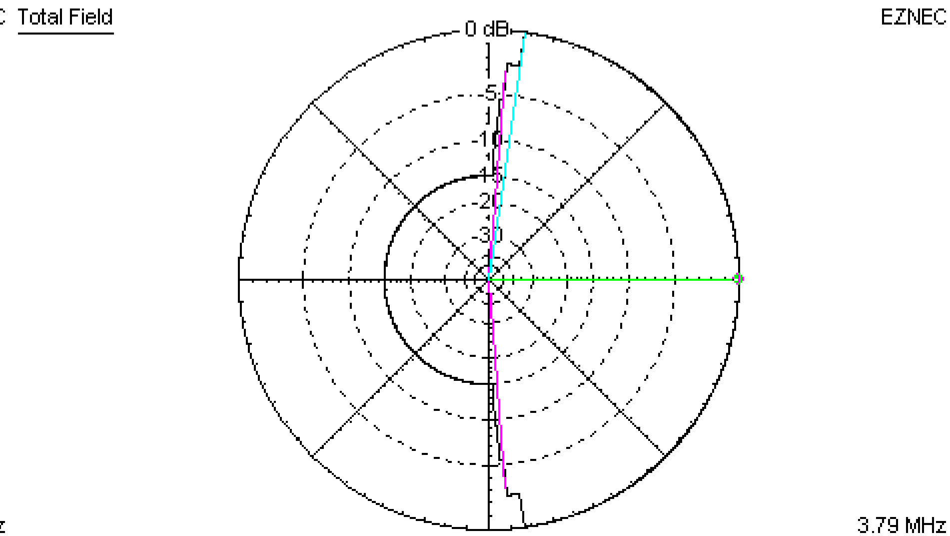
Vertical, sea water 20m away, 3m down

4 elevated radials up 3m
Elevation angles 5 and 2 deg



Azimuth Plot		Cursor Az	0.0 deg.
Elevation Angle	5.0 deg.	Gain	4.75 dBi
Outer Ring	4.75 dBi		0.0 dBmax
Slice Max Gain	4.75 dBi @ Az Angle = 0.0 deg.		
Front/Back	9.76 dB		
Beamwidth	157.0 deg.; -3dB @ 281.5, 78.5 deg.		
Sidelobe Gain	4.72 dBi @ Az Angle = 69.2 deg.		
Front/Sidelobe	0.04 dB		

10dB sea water gain on 5deg

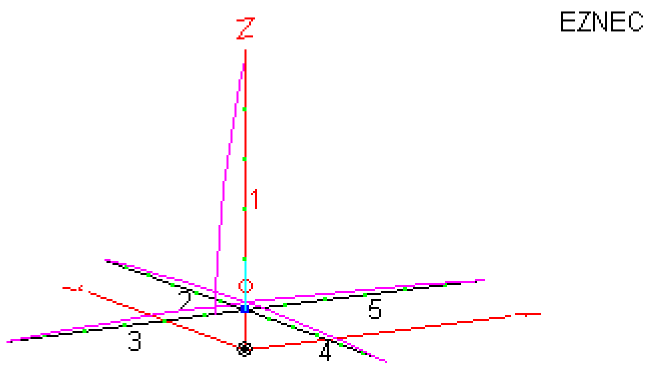


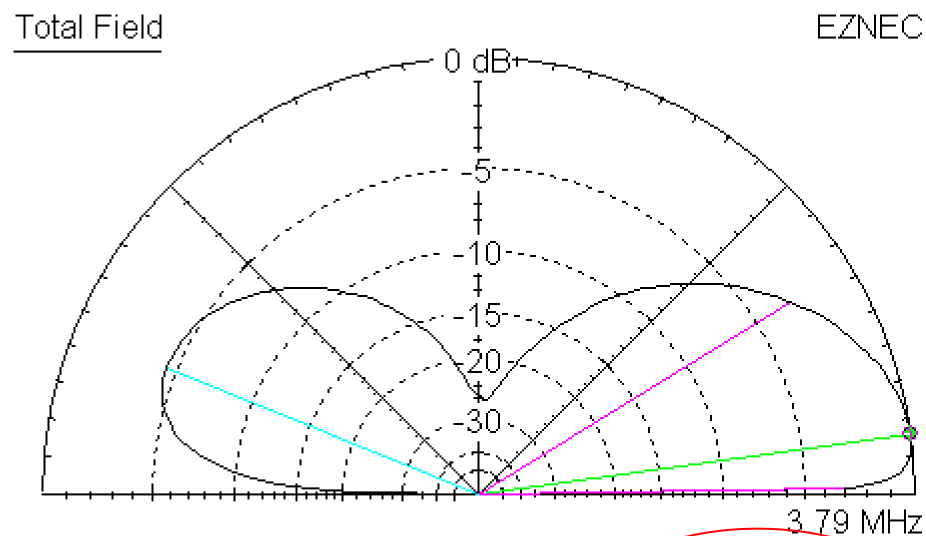
Azimuth Plot		Cursor Az	0.0 deg.
Elevation Angle	2.0 deg.	Gain	3.78 dBi
Outer Ring	3.78 dBi		0.0 dBmax
Slice Max Gain	3.78 dBi @ Az Angle = 0.0 deg.		
Front/Back	14.98 dB		
Beamwidth	170.8 deg.; -3dB @ 274.6, 85.4 deg.		
Sidelobe Gain	3.77 dBi @ Az Angle = 81.8 deg.		
Front/Sidelobe	0.01 dB		

15dB sea water gain on 2 deg

Vertical, sea water 0m away, 3m down

4 elevated radials up 3m





Elevation Plot	
Azimuth Angle	0.0 deg.
Outer Ring	4.9 dBi
Slice Max Gain	4.9 dBi @ Elev Angle = 8.0 deg.
Beamwidth	30.4 deg.; -3dB @ 1.0, 31.4 deg.
Sidelobe Gain	0.43 dBi @ Elev Angle = 158.0 deg.
Front/Sidelobe	4.47 dB

Cursor Elev	8.0 deg.
Gain	4.9 dBi
	0.0 dBmax

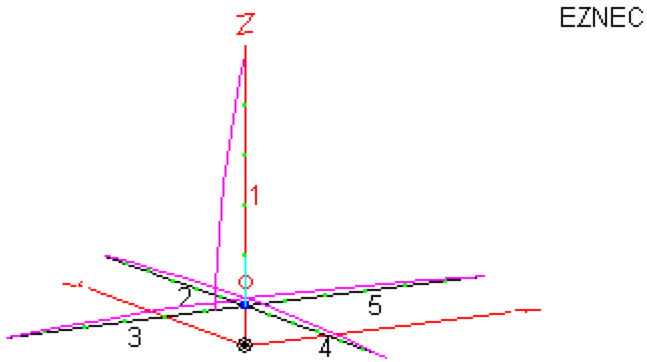
X<0m, Z=0, Average ground
5mS, Є=13

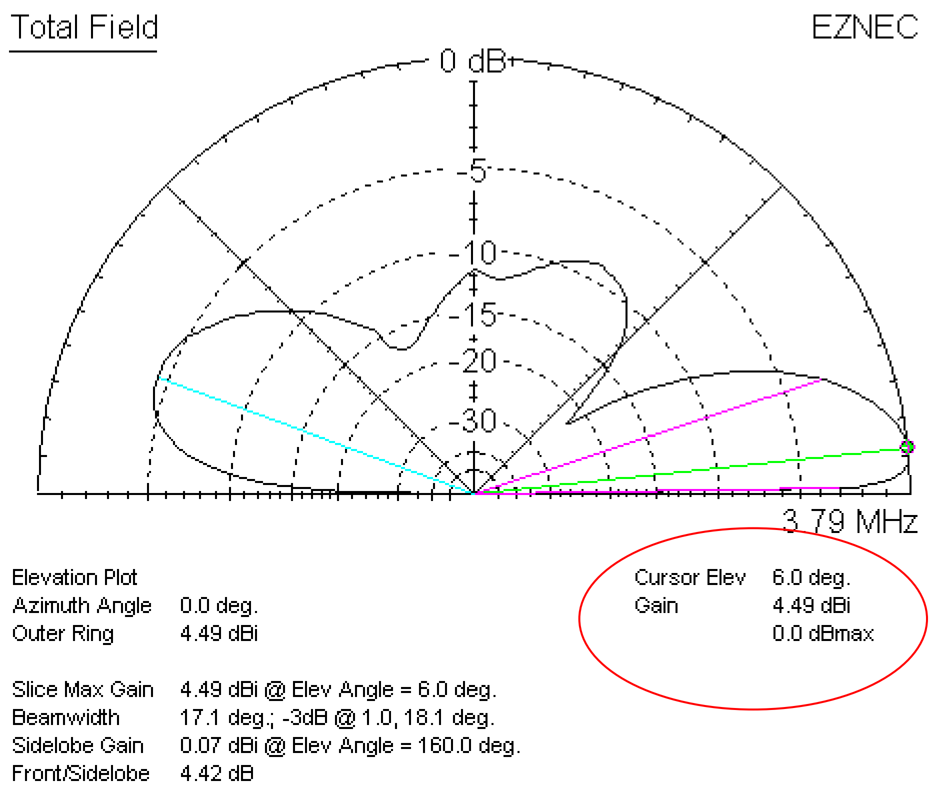
X>0m, Z=-3m, Sea water
2S, Є=80 (Baltic Sea)

4.6dB sea water gain

Vertical, sea water 0m away, 20m down

4 elevated radials up 3m





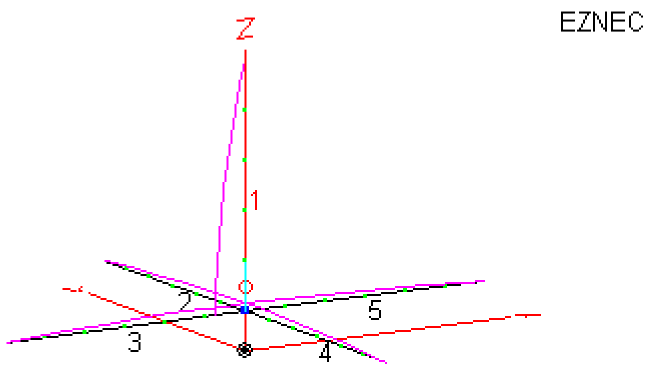
X<50m, Z=0, Average ground
5mS, Є=13

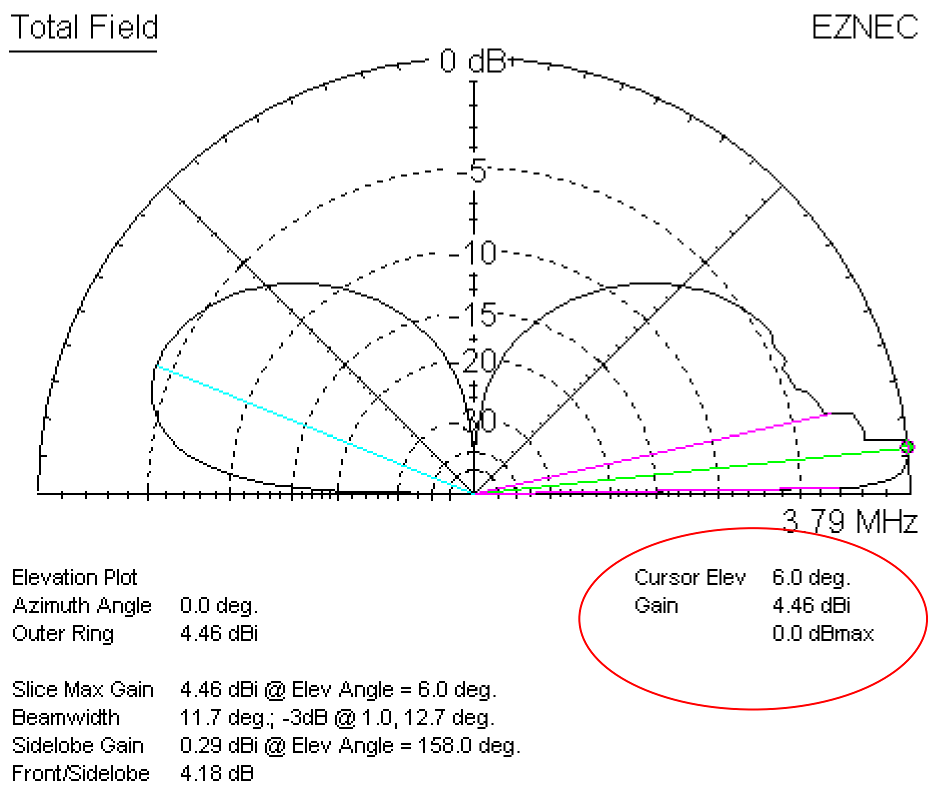
X>50m, Z=-20m, Sea water
2S, Є=80 (Baltic Sea)

4.2dB sea water gain

Vertical, sea water 40m away, 20m down

4 elevated radials 3m high





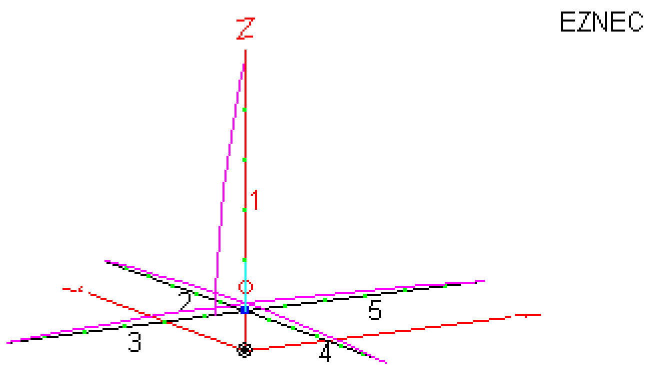
X<40m, Z=0, Average ground
5mS, Є=13

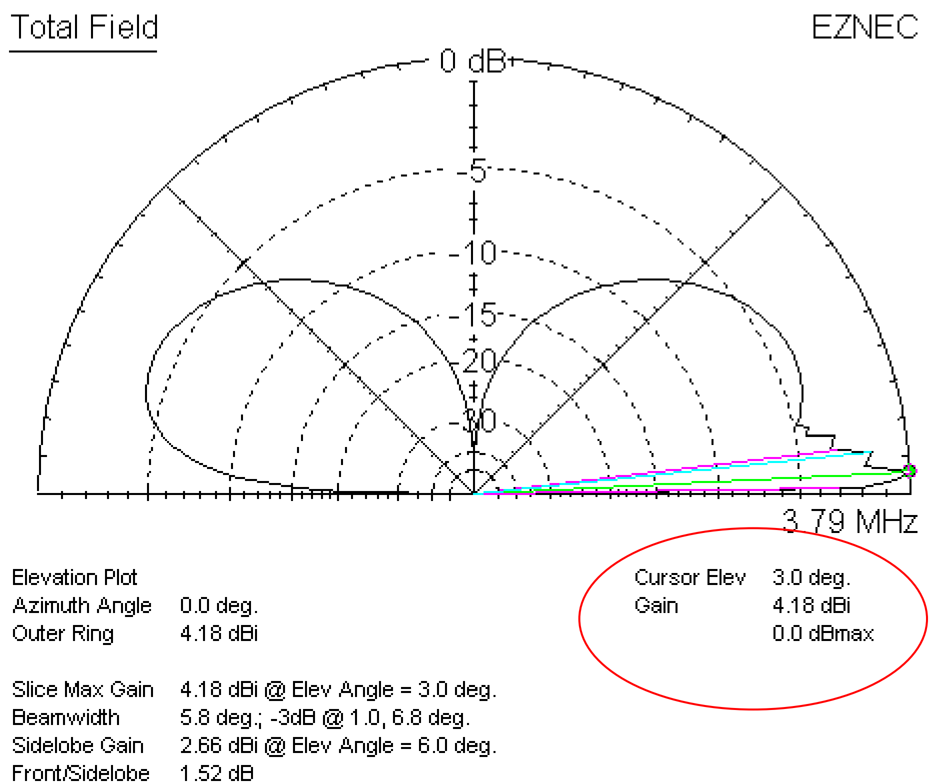
X>40m, Z=-20m, Sea water
2S, Є=80 (Baltic Sea)

4.26dB sea water gain

Vertical, sea water 80m away, 20m down

4 elevated radials up 3m





X<80m, Z=0, Average ground
5mS, Є=13

X>80m, Z=-20m, Sea water
2S, Є=80 (Baltic Sea)

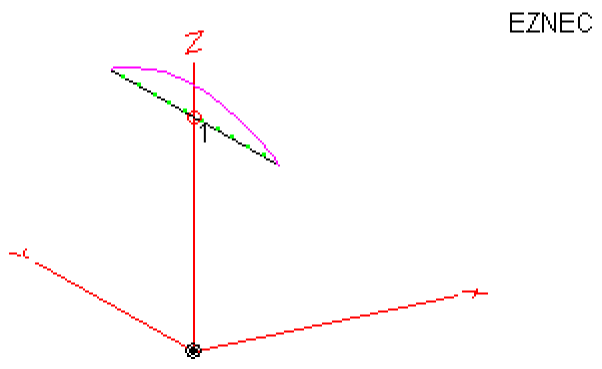
3.9dB sea water gain

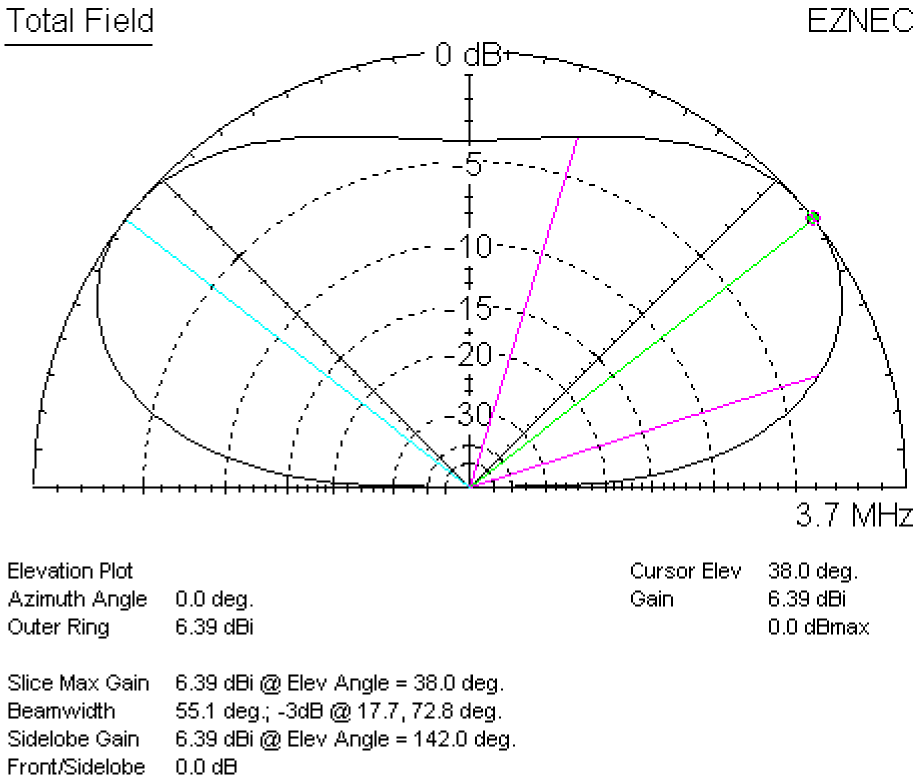
1. Influence of water on vertical antenna Conclusions:

- Fresh water provides very little help, a bit lowered TOA
- Sea water gives almost 5dB gain plus lower angle of radiation, effect is up to 3 S-units on low angles
  - Water line shall be less than ½ wavelengths from the antenna
- Antenna elevation from water provides no advantage
  - (elevated radials are ok)

2. Influence of nearby water on horizontal antenna

80m dipole up 30m
average ground

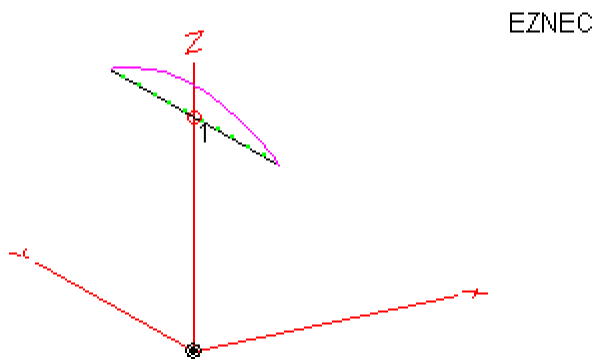


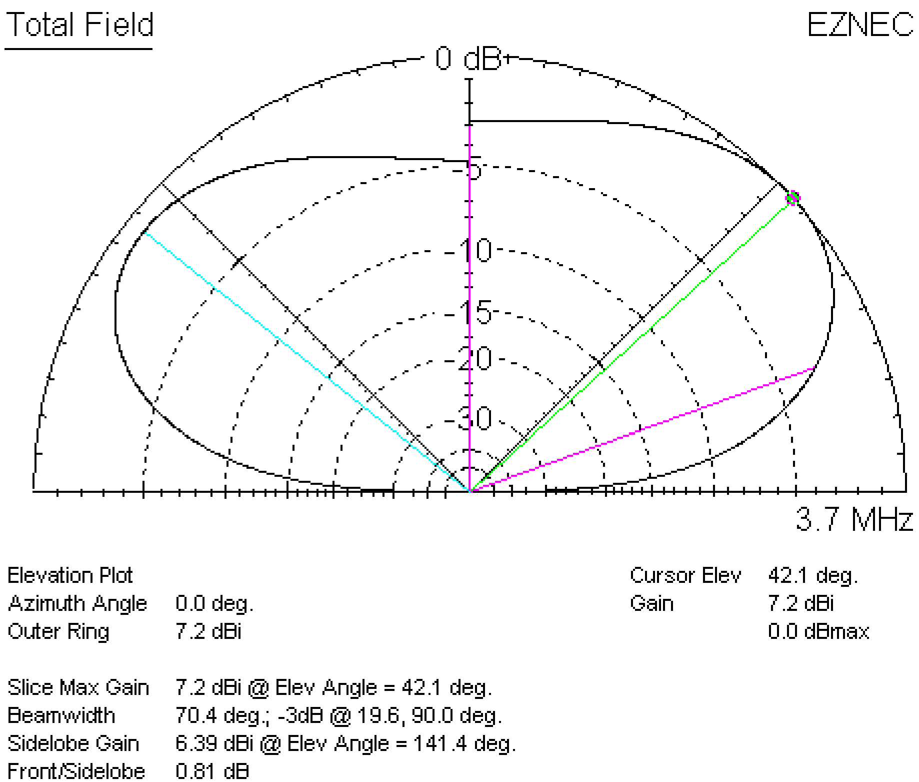


Average ground
5mS, Є=13

80m dipole up 30m

x<0 is average ground, x>0 is sea 0m down



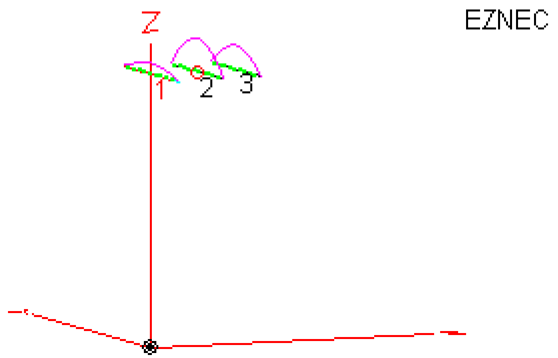


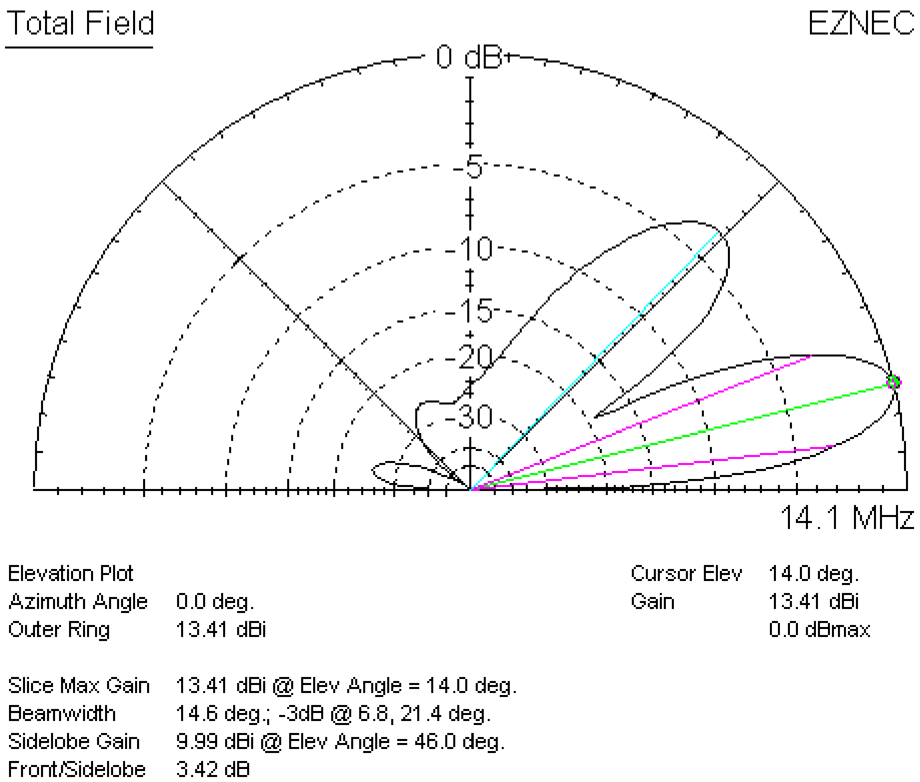
X<0m, Z=0, Average ground
5mS, Є=13

X>0m, Z=0m, Sea water
2S, Є=80 (Baltic Sea)

0.8dB sea water gain

3-el yagi up 21m
average flat ground



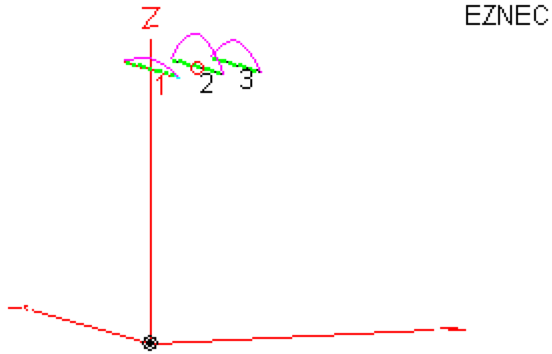


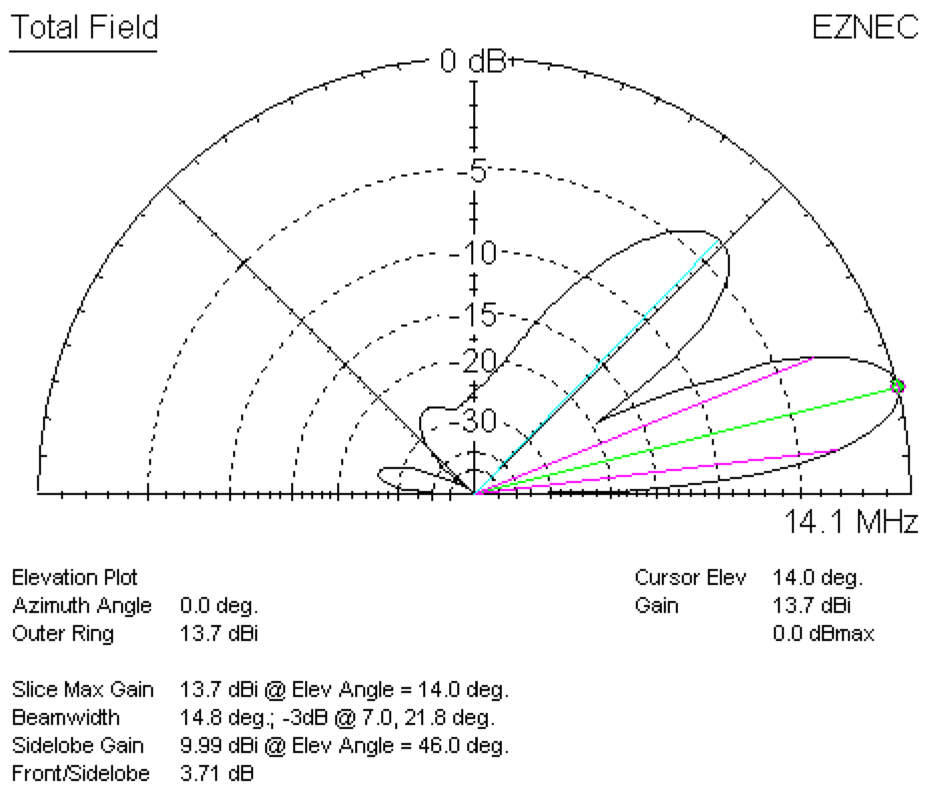
Average ground
5mS, Є=13

water gain reference

3-el yagi up 21m

fresh water 50m away





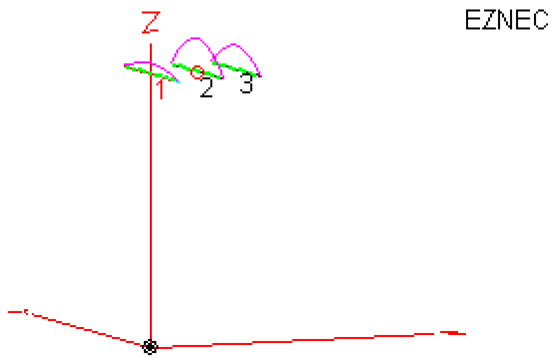
X<50m, Z=0, Average ground
5mS, Є=13

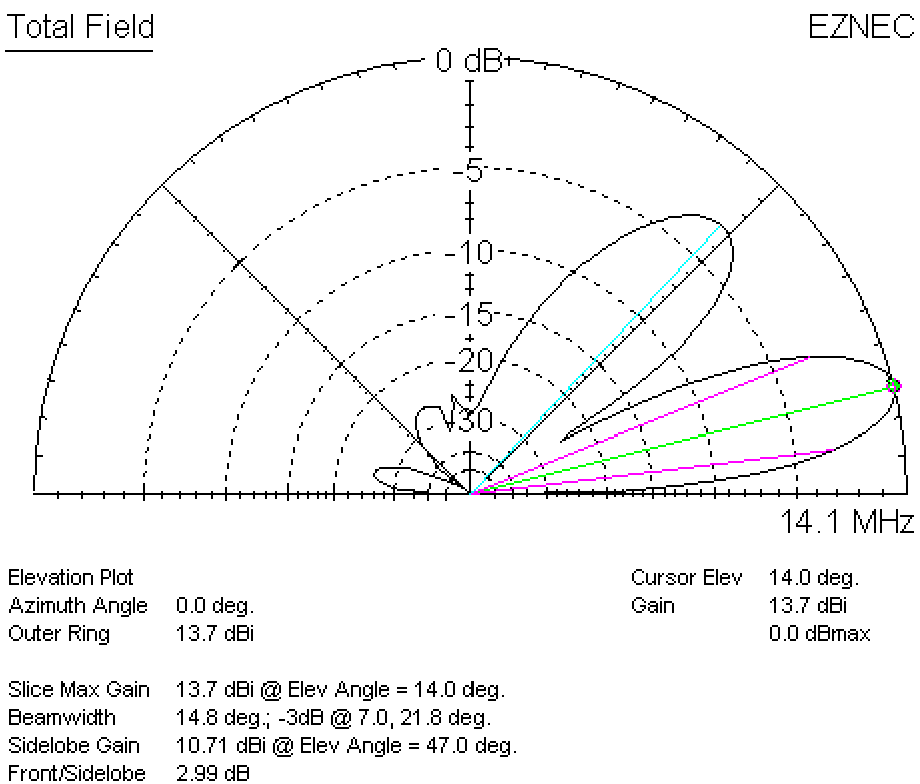
X>50m, Z=0, Fresh water
5mS, Є=80

0.3dB fresh water gain

3-el yagi up 21m

fresh water 0m away





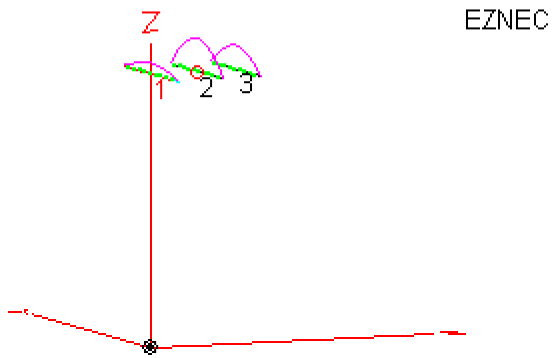
X<0m, Z=0, Average ground
5mS, Є=13

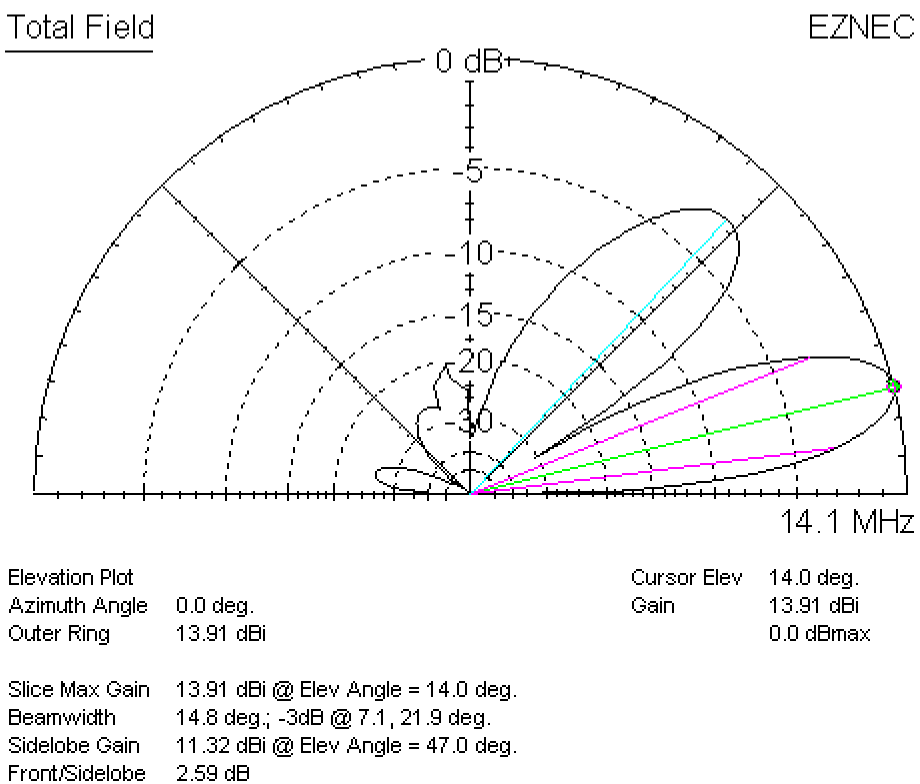
X>0m, Z=0, Fresh water
5mS, Є=80

0.3dB fresh water gain

3-el yagi up 21m

sea water 0m away





X<0m, Z=0, Average ground
5mS, Є=13

X>0m, Z=0m, Sea water
2S, Є=80 (Baltic Sea)

0.5dB sea water gain

2. Influence of nearby water on horizontal antenna Conclusions:

- Fresh water has practically no influence
- Even sea water increases gain only by 1/2dB

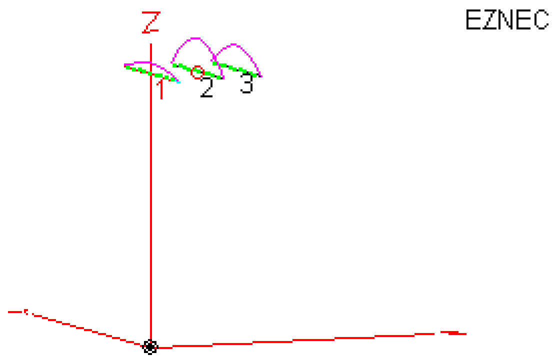
- Horizontal antennas depend very little on quality of ground

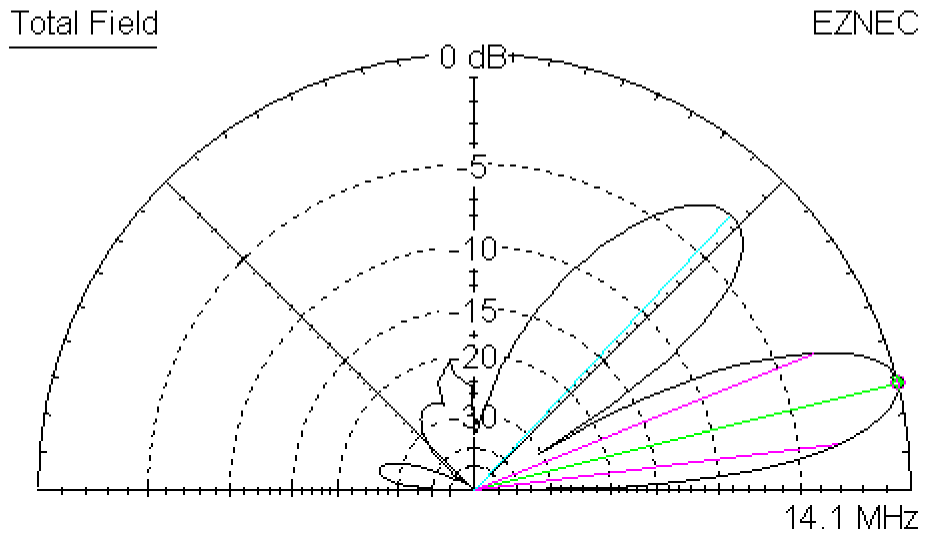
Seaside QTH provides very little advantage, when using horizontal antennas

3. Influence of steep coast on horizontal antenna

3-el yagi 14100kHz up 21m

sea water 0m away, 0m down (reference)





Elevation Plot		Cursor Elev	14.0 deg.
Azimuth Angle	0.0 deg.	Gain	13.91 dBi
Outer Ring	13.91 dBi		0.0 dBmax

Slice Max Gain 13.91 dBi @ Elev Angle = 14.0 deg.
Beamwidth 14.8 deg.; -3dB @ 7.1, 21.9 deg.
Sidelobe Gain 11.32 dBi @ Elev Angle = 47.0 deg.
Front/Sidelobe 2.59 dB

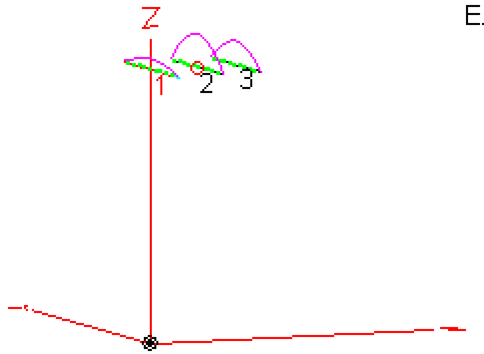
X<0m, Z=0, Average ground
5mS, Є=13

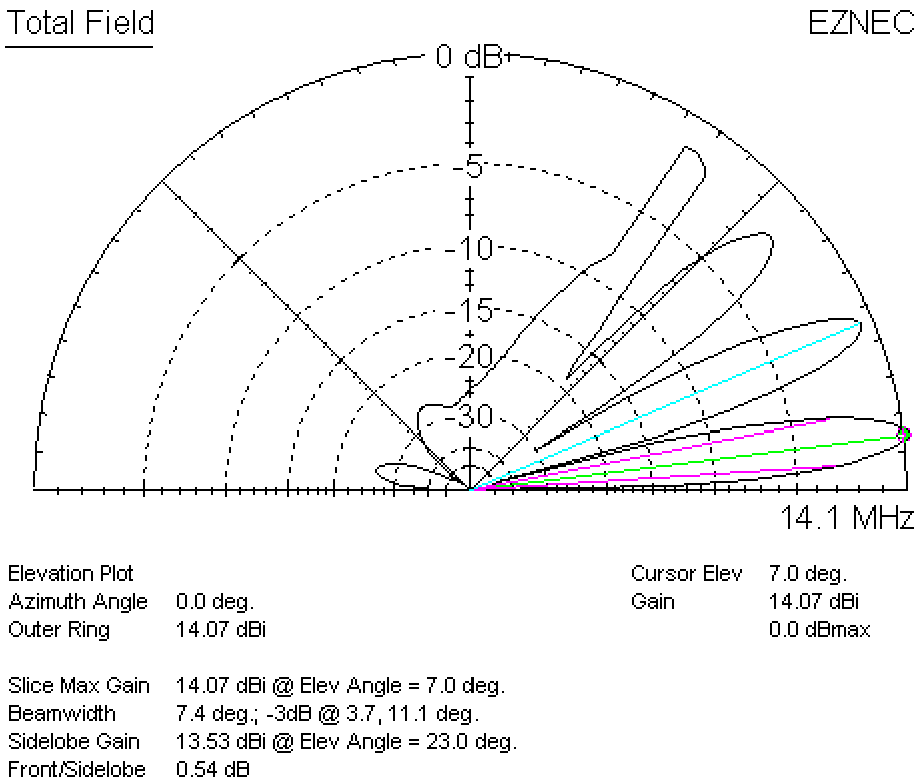
X>0m, Z=0m, Sea water
2S, Є=80 (Baltic Sea)

cliff gain reference

3-el yagi up 21m

sea water 20m away, 20m down





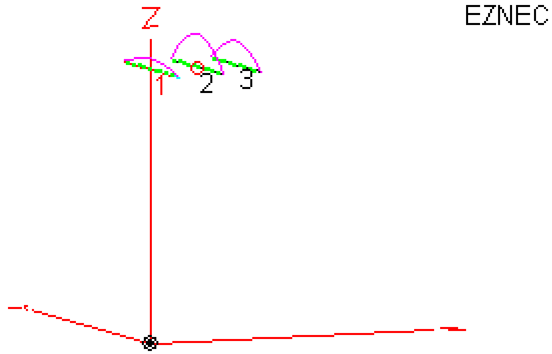
X<20m, Z=0, Average ground
5mS, Є=13

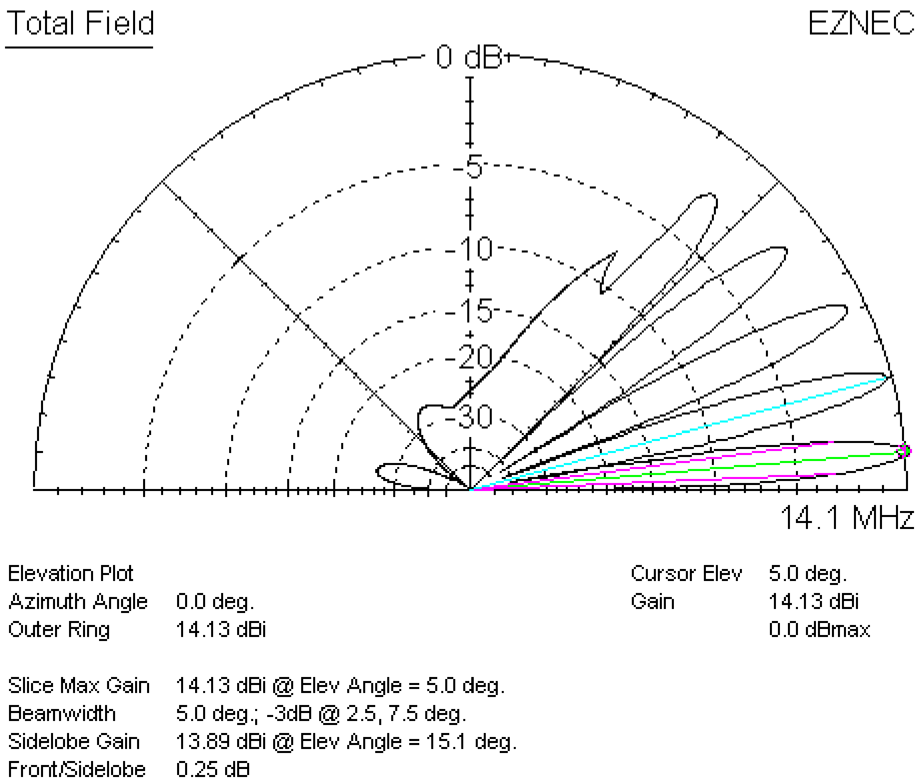
X>20m, Z=-20m, Sea water
2S, Є=80 (Baltic Sea)

0.16dB cliff gain
7deg lowered TOA

3-el yagi up 21m

sea water 20m away, 40m down





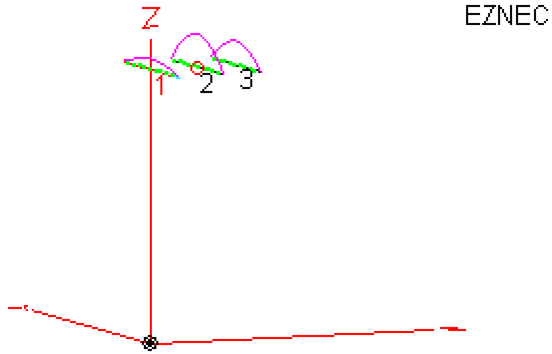
X<20m, Z=0, Average ground
5mS, Є=13

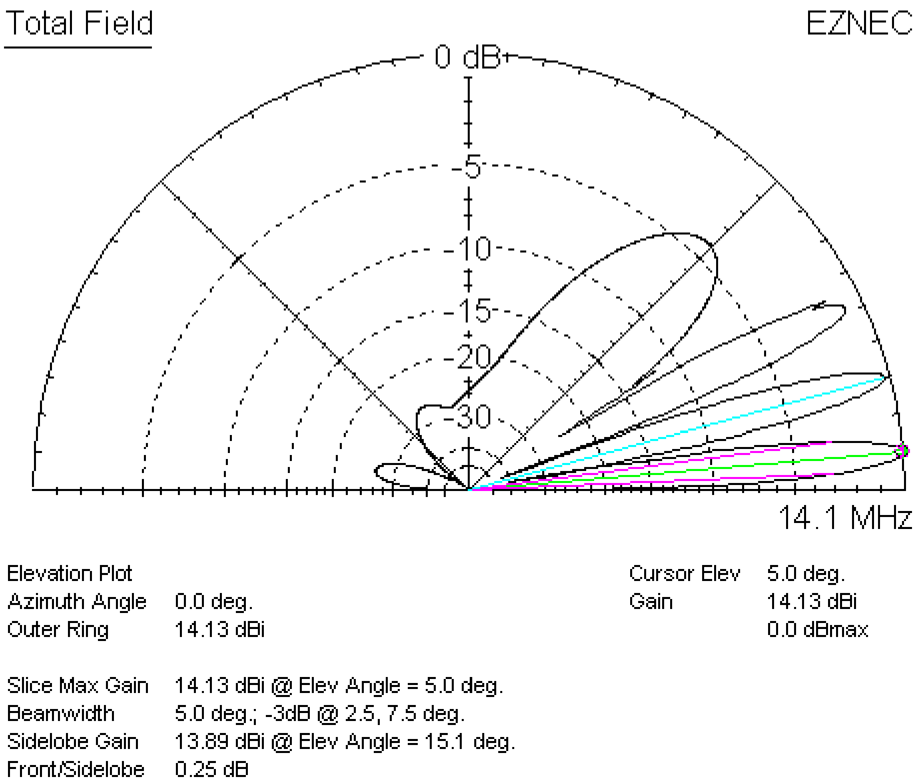
X>20m, Z=-40m, Sea water
2S, Є=80 (Baltic Sea)

0.22dB cliff gain
9deg lowered TOA

3-el yagi up 21m

sea water 40m away, 40m down





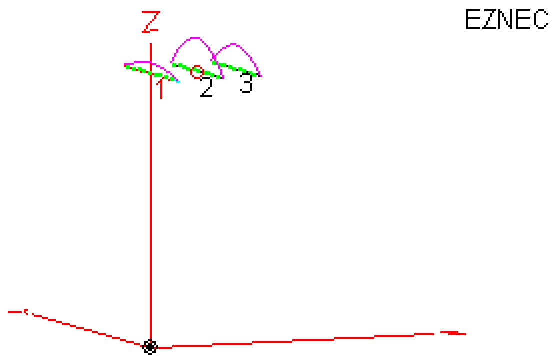
X<40m, Z=0, Average ground 5mS, Є=13

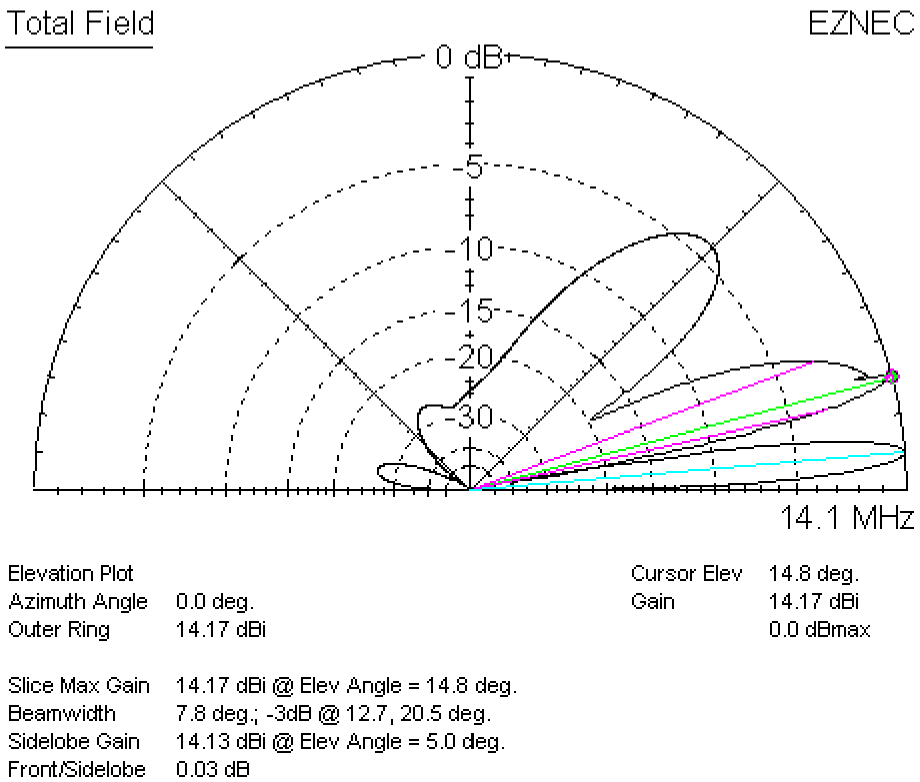
X>40m, Z=-40m, Sea water 2S, Є=80 (Baltic Sea)

0.22dB cliff gain
9deg lowered TOA

3-el yagi up 21m

sea water 80m away, 40m down





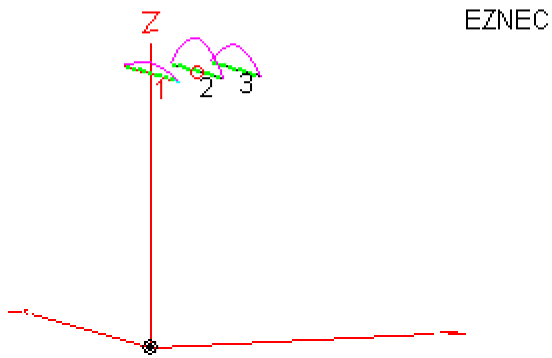
X<80m, Z=0, Average ground
5mS, Є=13

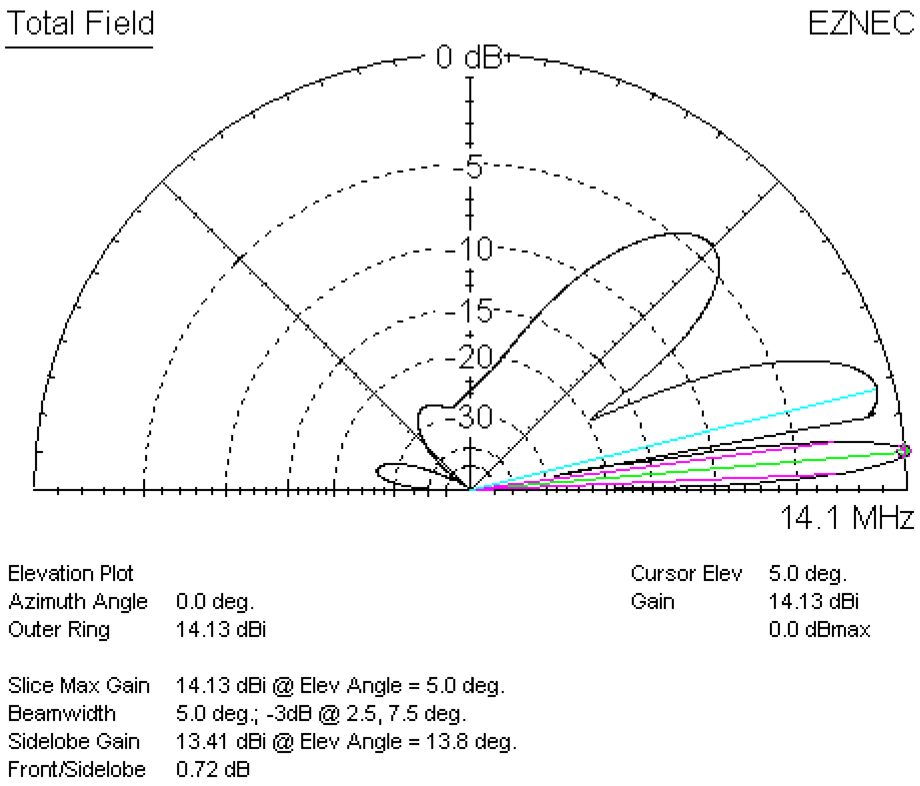
X>80m, Z=-40m, Sea water
2S, Є=80 (Baltic Sea)

0.26dB cliff gain
additional 7deg lower TOA

3-el yagi up 21m

sea water 120m away, 40m down





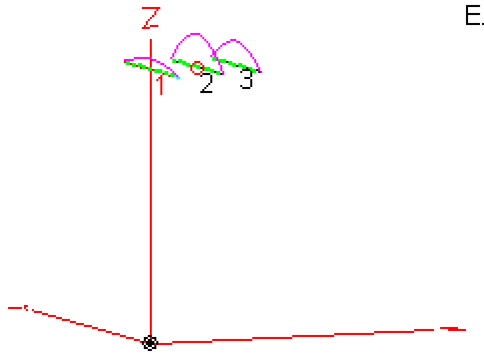
X<120m, Z=0, Average ground
5mS, Є=13

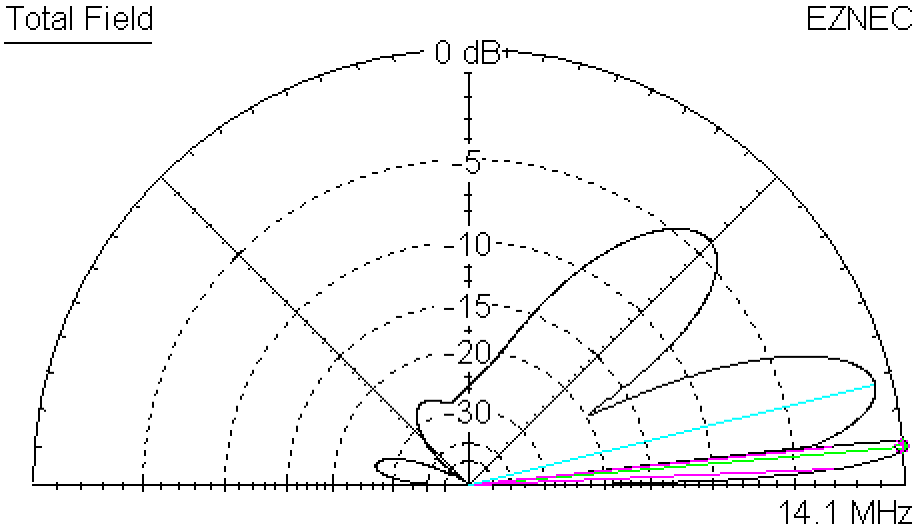
X>120m, Z=-40m, Sea water
2S, Є=80 (Baltic Sea)

0.22dB cliff gain
9deg lowered TOA

3-el yagi up 21m

sea water 200m away, 40m down





Elevation Plot
Azimuth Angle 0.0 deg.
Outer Ring 14.13 dBi

Cursor Elev 5.0 deg.
Gain 14.13 dBi
0.0 dBmax

Slice Max Gain 14.13 dBi @ Elev Angle = 5.0 deg.
Beamwidth 3.6 deg.; -3dB @ 2.5, 6.1 deg.
Sidelobe Gain 13.41 dBi @ Elev Angle = 13.8 deg.
Front/Sidelobe 0.72 dB

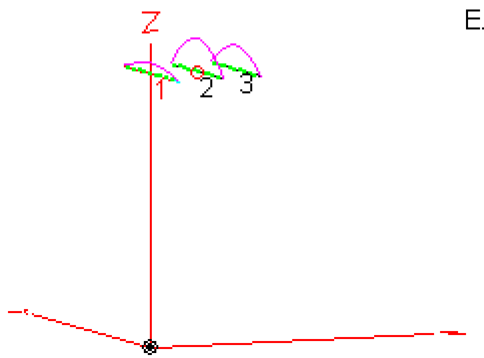
X<200m, Z=0, Average ground
5mS, Є=13

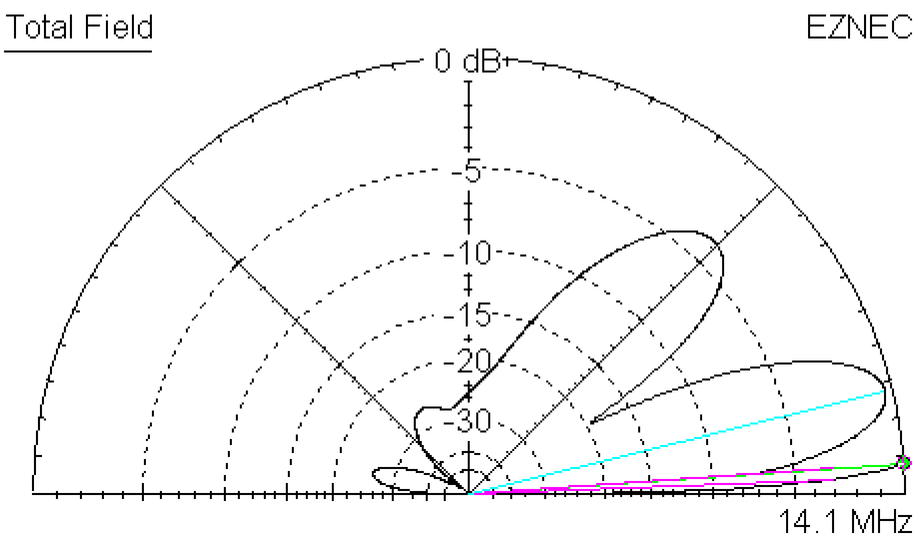
X>200m, Z=-40m, Sea water
2S, Є=80 (Baltic Sea)

0.22dB cliff gain
9deg lowered TOA

3-el yagi up 21m

sea water 300m away, 40m down





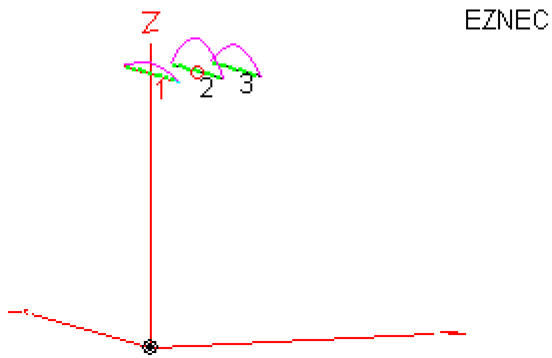
X<300m, Z=0, Average ground
5mS, Є=13

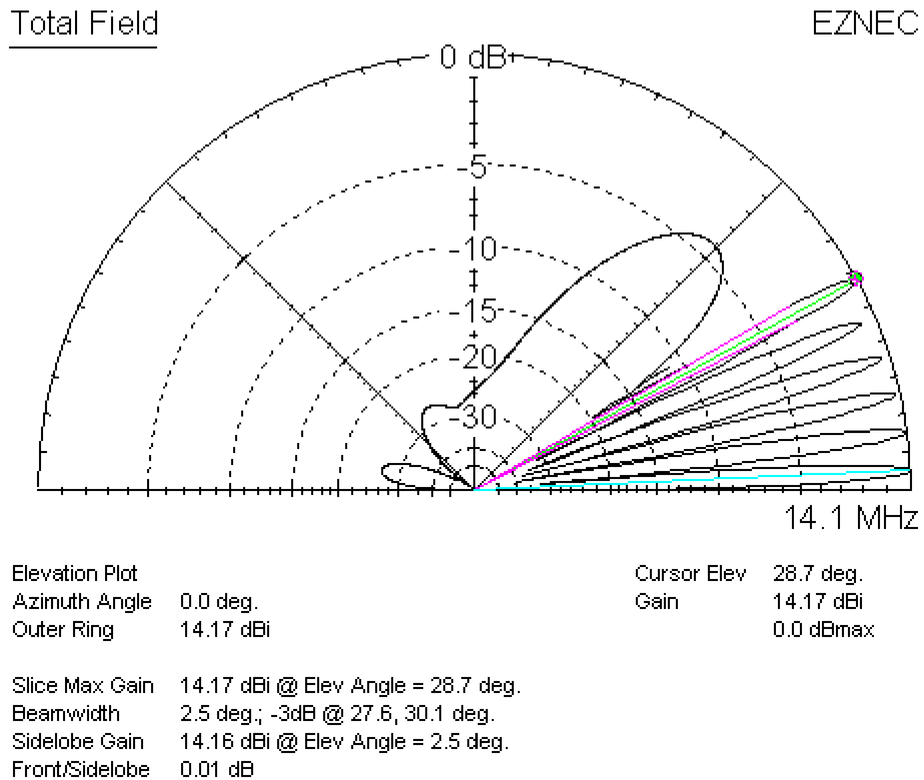
X>300m, Z=-40m, Sea water
2S, Є=80 (Baltic Sea)

-0.2dB cliff gain
additional 10deg lower TOA

3-el yagi up 21m

sea water 40m away, 100m down





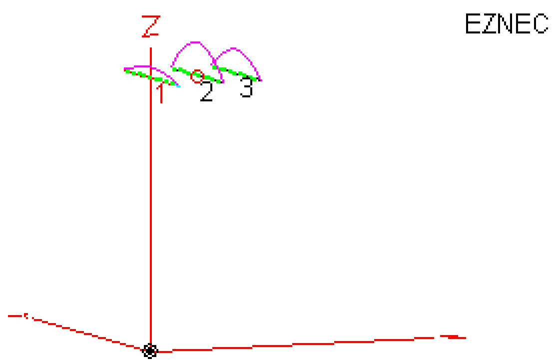
X<40m, Z=0, Average ground
5mS, Є=13

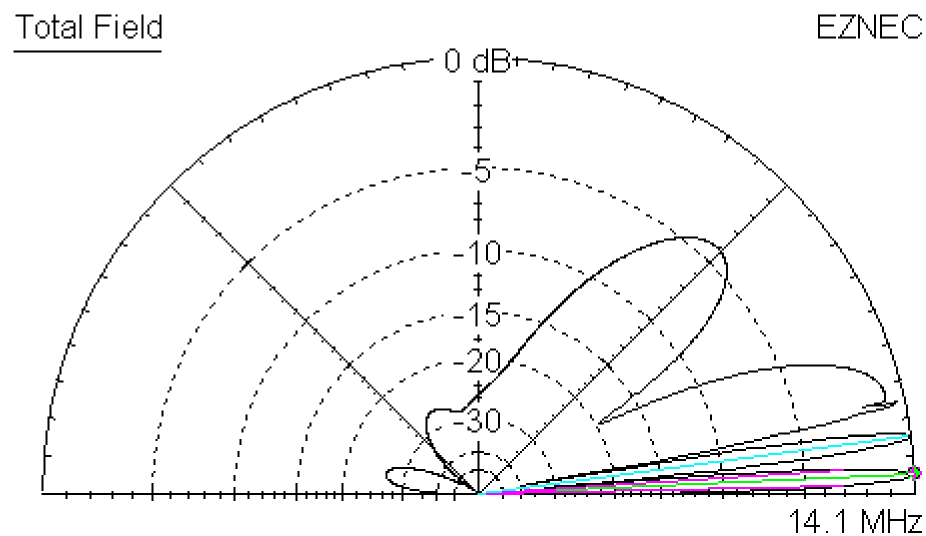
X>40m, Z=-100m, Sea water
2S, Є=80 (Baltic Sea)

0.26dB cliff gain
multiple TOA down to 2.5deg

3-el yagi up 21m

sea water 100m away, 100m down





Elevation Plot		Cursor Elev	2.5 deg.
Azimuth Angle	0.0 deg.	Gain	14.16 dBi
Outer Ring	14.16 dBi		0.0 dBmax

Slice Max Gain	14.16 dBi @ Elev Angle = 2.5 deg.
Beamwidth	2.5 deg.; -3dB @ 1.3, 3.8 deg.
Sidelobe Gain	14.09 dBi @ Elev Angle = 7.6 deg.
Front/Sidelobe	0.07 dB

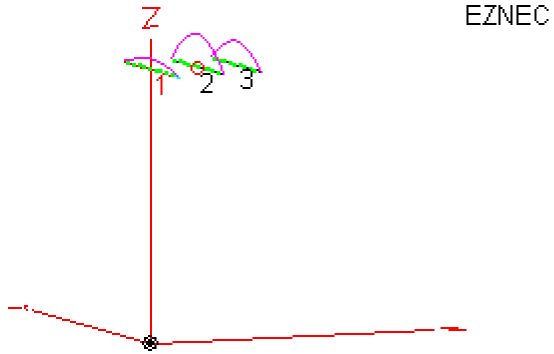
X<100m, Z=0, Average ground
5mS, Є=13

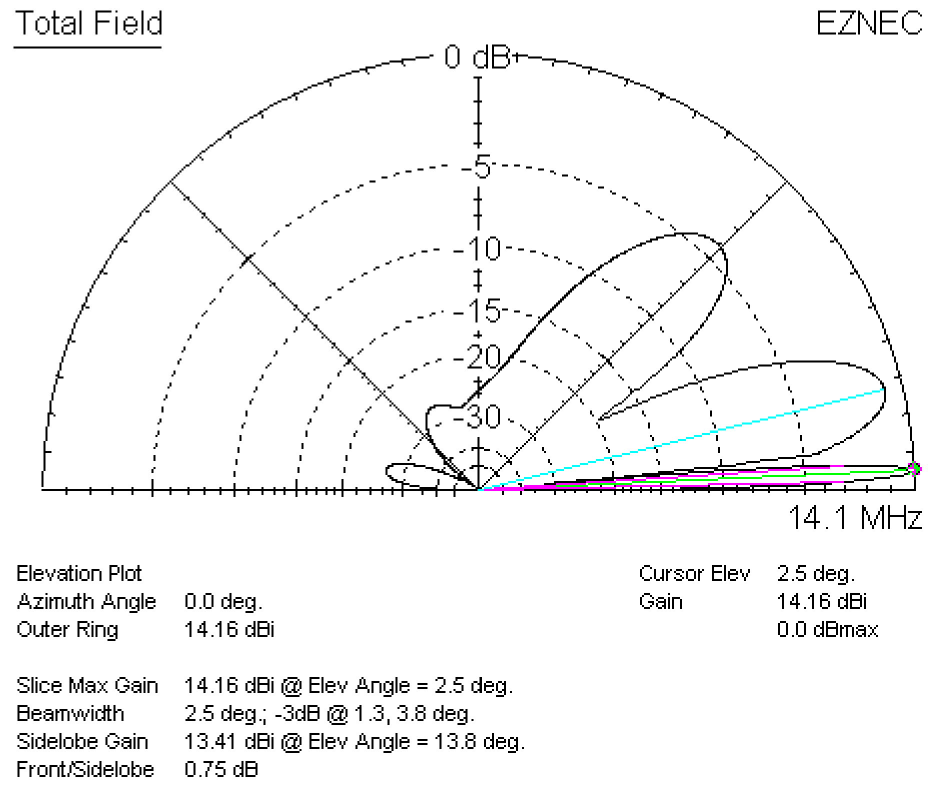
X>100m, Z=-100m, Sea water
2S, Є=80 (Baltic Sea)

0.25dB cliff gain
11.5deg lowered TOA
Multiple TOA's

3-el yagi up 21m

sea water 200m away, 100m down





X<200m, Z=0, Average ground
5mS, Є=13

X>200m, Z=-100m, Sea water
2S, Є=80 (Baltic Sea)

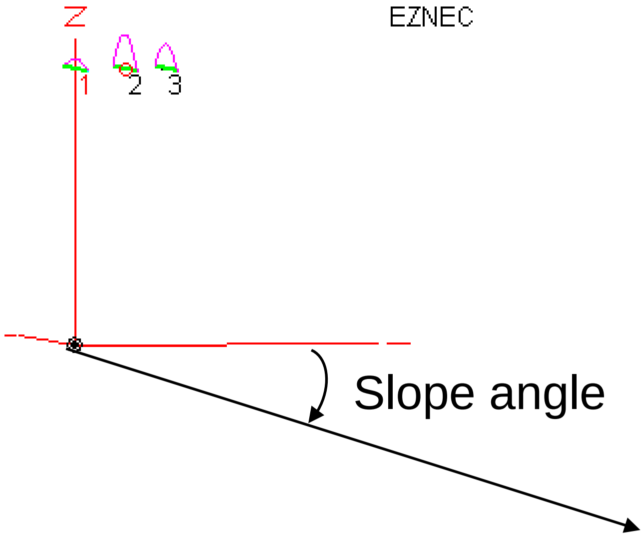
0.25dB cliff gain
11.5deg lowered TOA

3. Influence of steep cliff on horizontal antenna Conclusions:

- Nearby cliff has the same influence as tower height
  - Lower TOA
  - a bit more gain
- Distance to cliff can be quite long for low TOA’s
  - In the example
    - Antenna height 1 lamda
    - Cliff height 2 lamda
    - >Cliff distance can be up to 6 lamda
- Distance to cliff lowers secondary lobes
- Deep reflector can be any type of soil, doesn’t need to be sea water

4. Influence of sloping terrain on horizontal antenna

TOA of Hill Top QTH

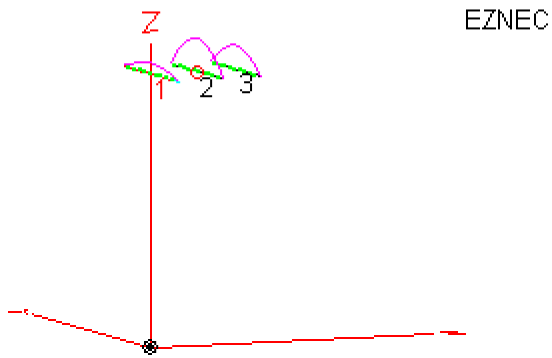


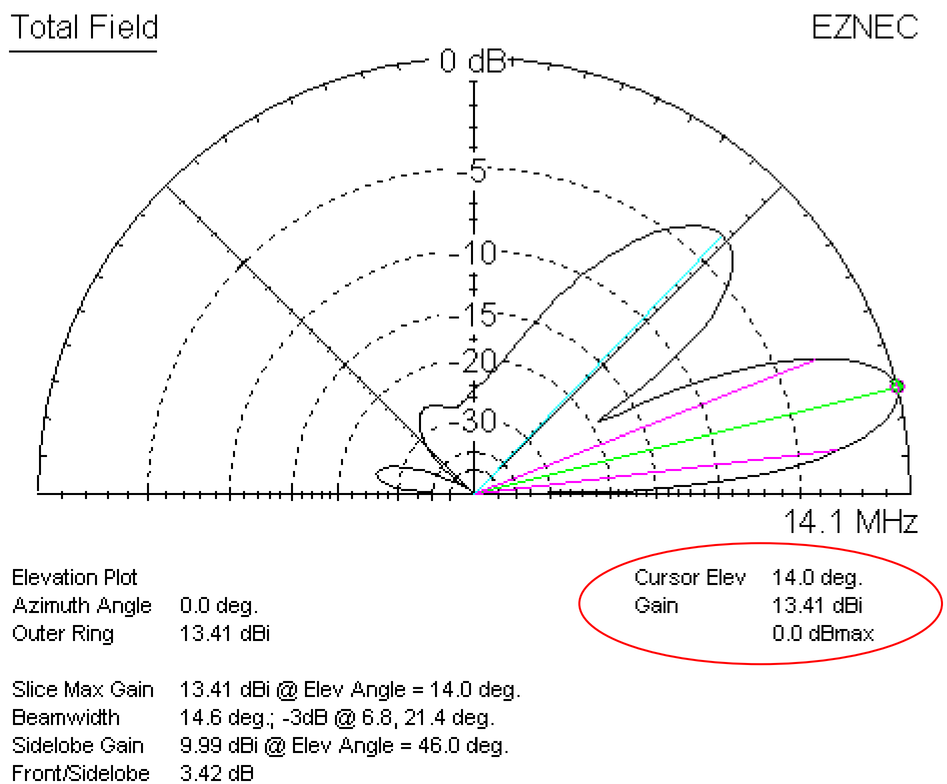
TOA = TOA (on flat surface) – slope angle

This can become even negative which is not useful

5. Influence of stacking

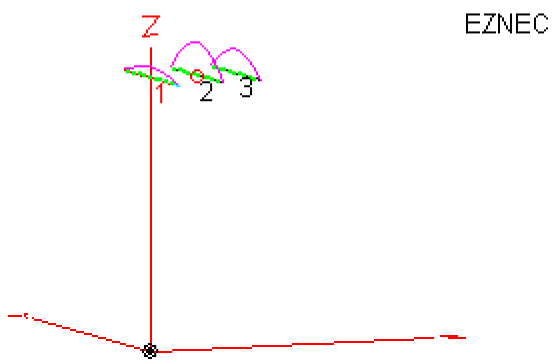
3-el yagi 1 wavelength high
average flat ground

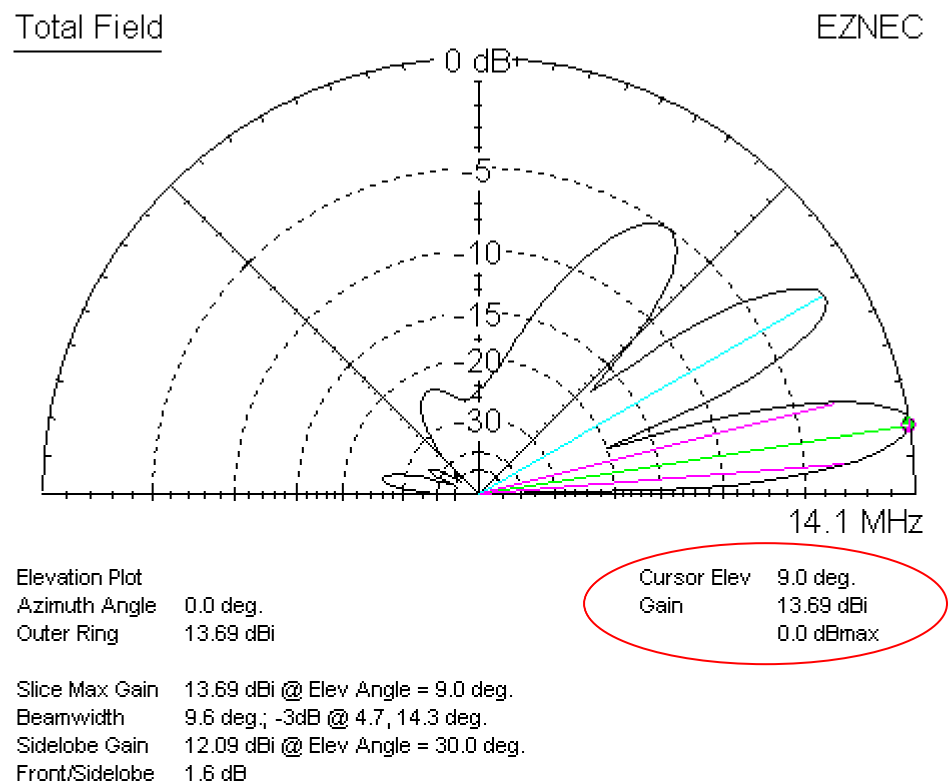




Average ground
5mS, Є=13

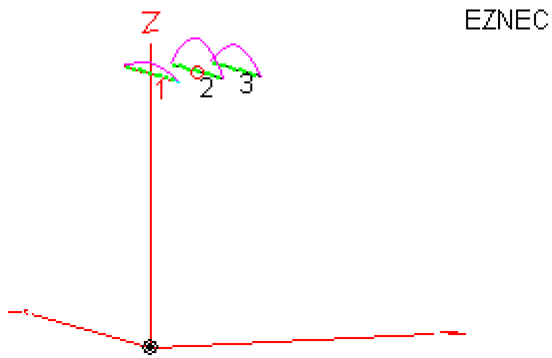
3-el yagi 1.5 wavelength high
average flat ground

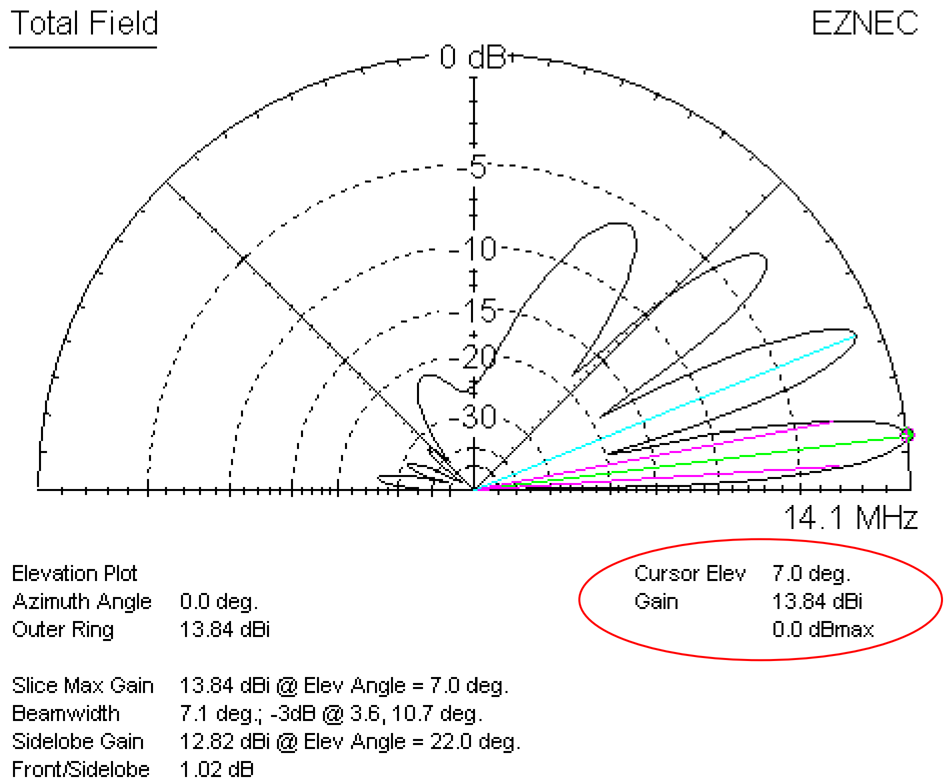




Average ground
5mS, Є=13

3-el yagi 2 wavelength high
average flat ground

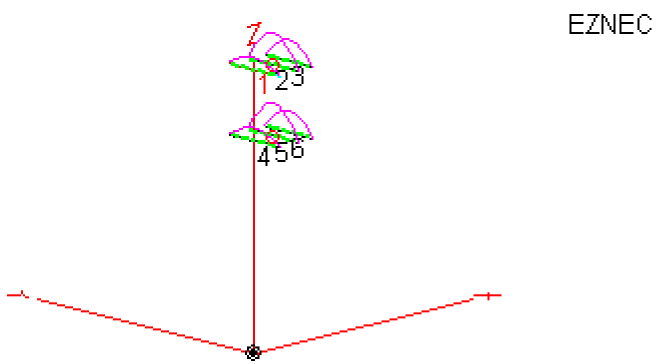


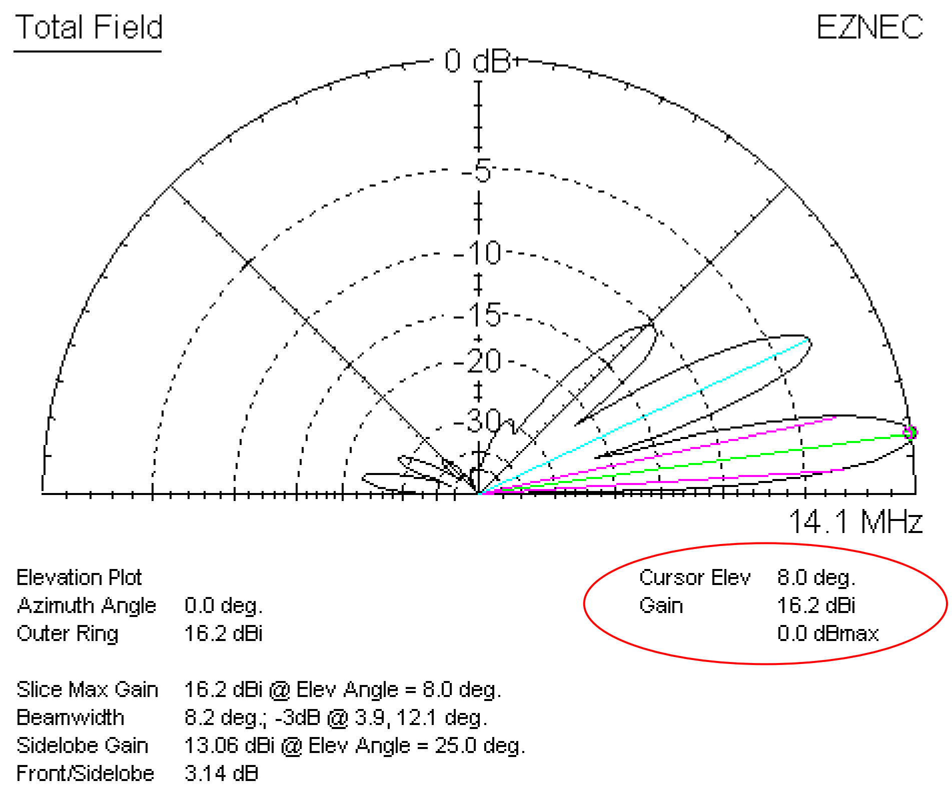


Average ground
5mS, Є=13

Stacked 2x 3-el yagi's

1.5 and 2.0 wavelength high



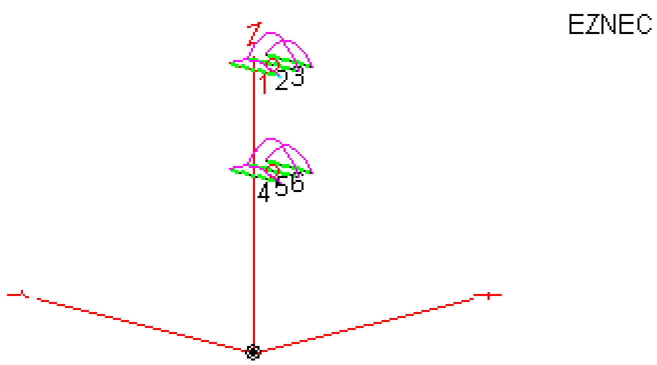


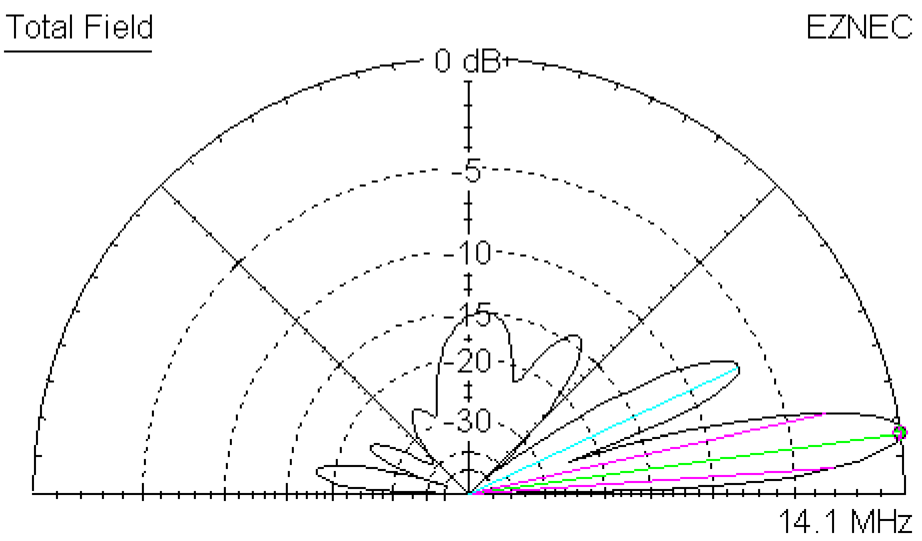
Average ground
5mS, Є=13

2.36dB stacking gain

Stacked 2x 3-el yagi's

1.25 and 2.0 wavelength high





Elevation Plot
Azimuth Angle 0.0 deg.
Outer Ring 16.49 dBi

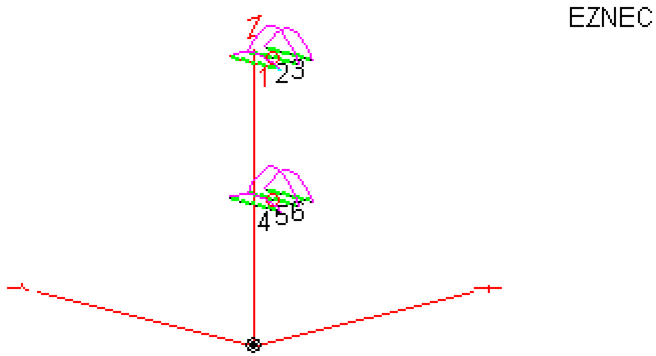
Cursor Elev 8.0 deg.
Gain 16.49 dBi
0.0 dBmax

Slice Max Gain 16.49 dBi @ Elev Angle = 8.0 deg.
Beamwidth 8.6 deg.; -3dB @ 4.1, 12.7 deg.
Sidelobe Gain 10.0 dBi @ Elev Angle = 25.0 deg.
Front/Sidelobe 6.49 dB

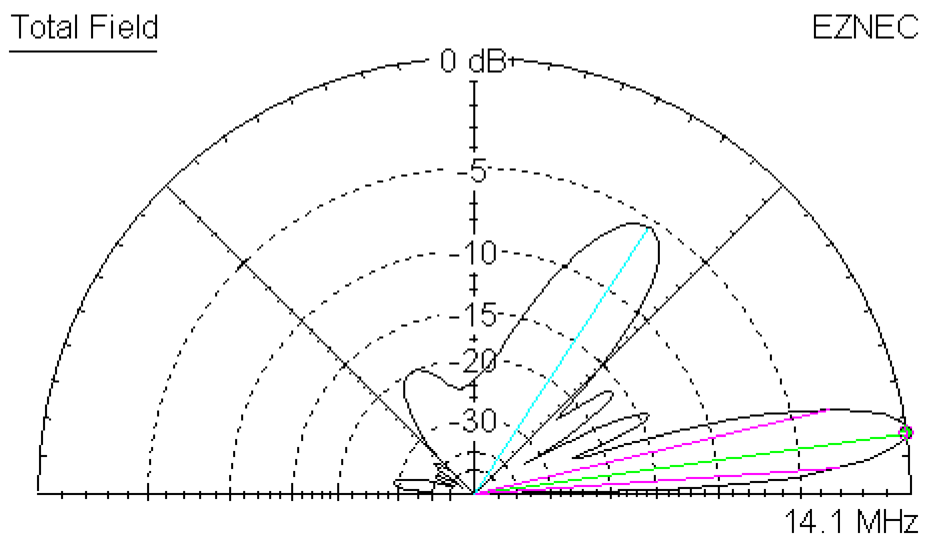
Average ground
5mS, Є=13

2.65dB stacking gain

Stacked 2x 3-el yagi's
1.0 and 2.0 wavelength high



Average ground
5mS, Є=13



Elevation Plot	
Azimuth Angle	0.0 deg.
Outer Ring	15.75 dBi

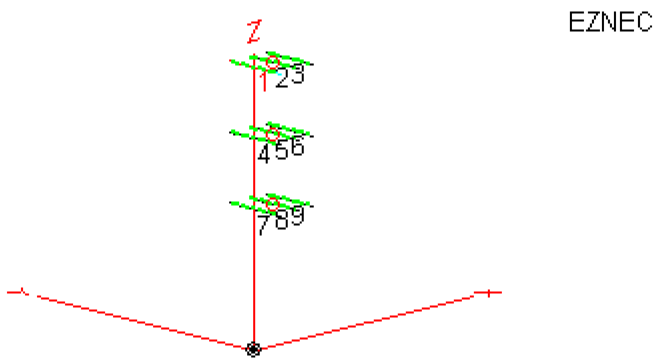
Cursor Elev	8.0 deg.
Gain	15.75 dBi
	0.0 dBmax

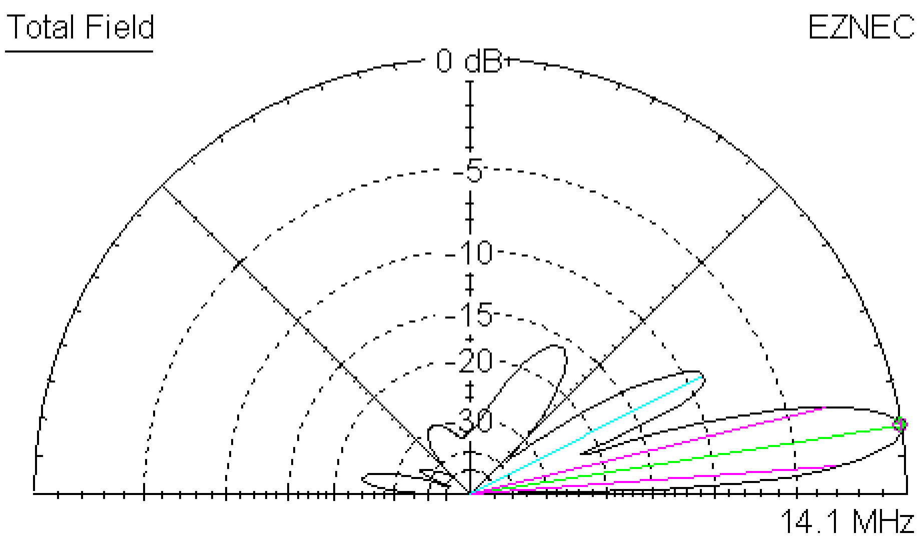
Slice Max Gain	15.75 dBi @ Elev Angle = 8.0 deg.
Beamwidth	9.0 deg.; -3dB @ 4.1, 13.1 deg.
Sidelobe Gain	10.31 dBi @ Elev Angle = 57.0 deg.
Front/Sidelobe	5.44 dB

1.91dB stacking gain

Stacked 3 x 3-el yagi's

1.0, 1.5 and 2.0 wavelength high, equal powers





Elevation Plot
Azimuth Angle 0.0 deg.
Outer Ring 17.25 dBi

Cursor Elev 9.0 deg.
Gain 17.25 dBi
0.0 dBmax

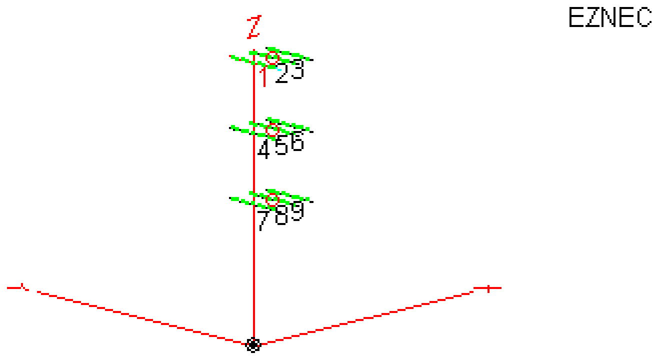
Slice Max Gain 17.25 dBi @ Elev Angle = 9.0 deg.
Beamwidth 9.2 deg.; -3dB @ 4.3, 13.5 deg.
Sidelobe Gain 8.46 dBi @ Elev Angle = 27.0 deg.
Front/Sidelobe 8.79 dB

Average ground
5mS, Є=13

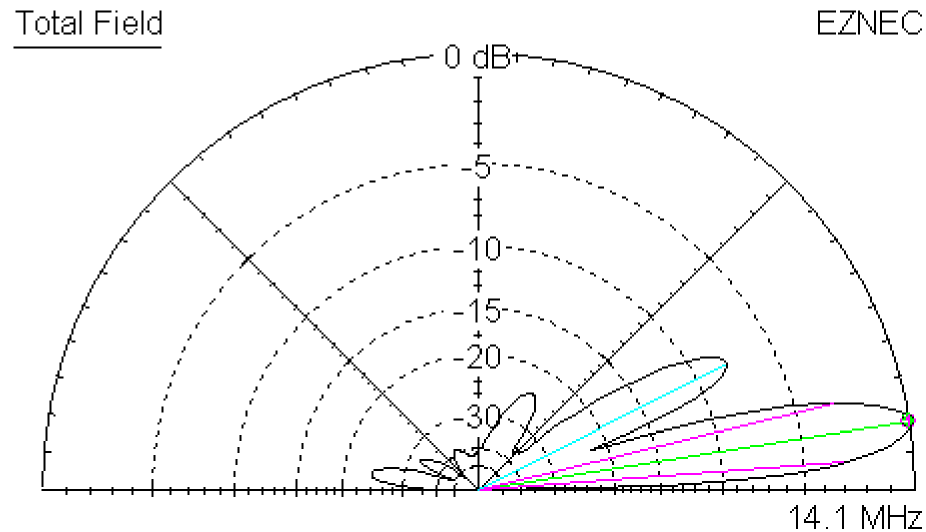
3.41dB stacking gain

Stacked 3 x 3-el yagi’s

1.0, 1.5 and 2.0 wavelength high, powers 1:2:1



Average ground
5mS, Є=13



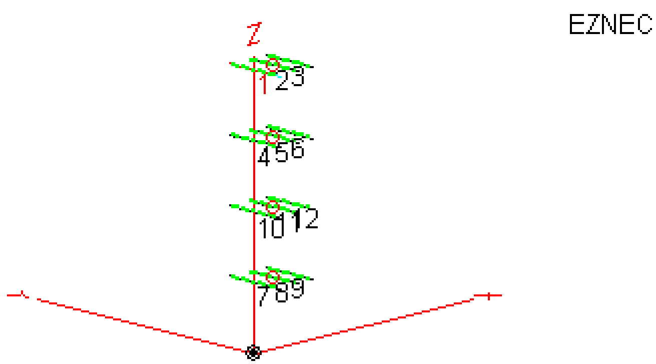
Elevation Plot	
Azimuth Angle	0.0 deg.
Outer Ring	17.21 dBi
Slice Max Gain	17.21 dBi @ Elev Angle = 9.0 deg.
Beamwidth	9.3 deg.; -3dB @ 4.3, 13.6 deg.
Sidelobe Gain	9.53 dBi @ Elev Angle = 27.0 deg.
Front/Sidelobe	7.68 dB

Cursor Elev	9.0 deg.
Gain	17.21 dBi
	0.0 dBmax

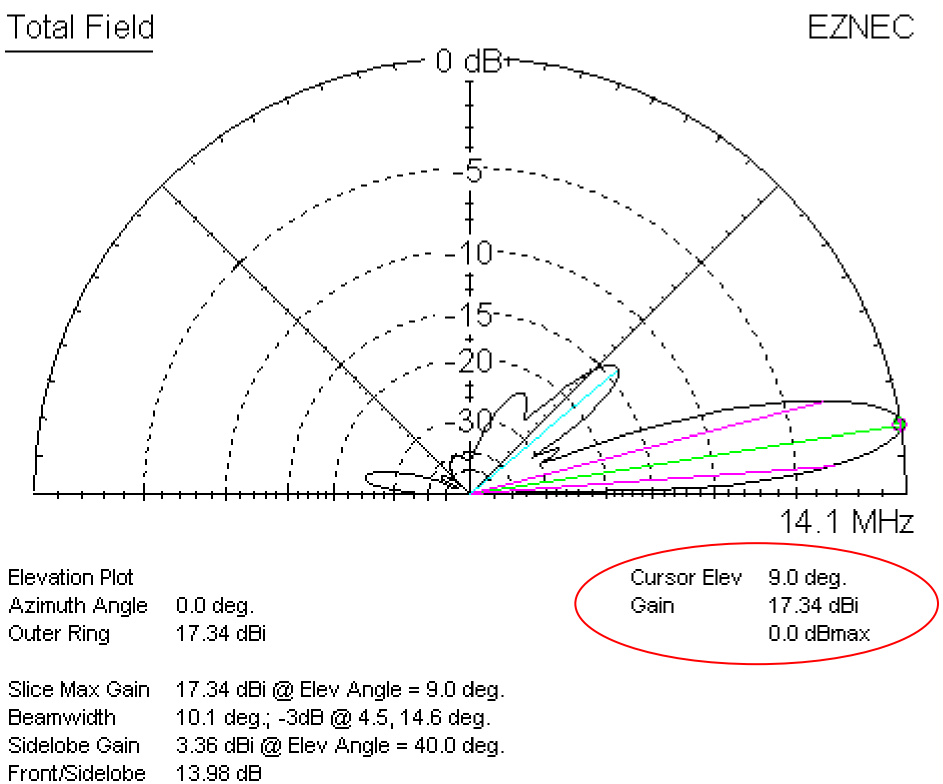
3.37dB stacking gain

Stacked 4 x 3-el yagi's

0.5, 1.0, 1.5 and 2.0 wavelength high, equal powers



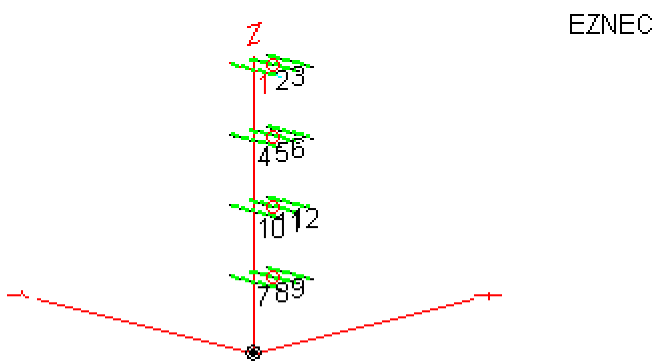
Average ground
5mS, Є=13



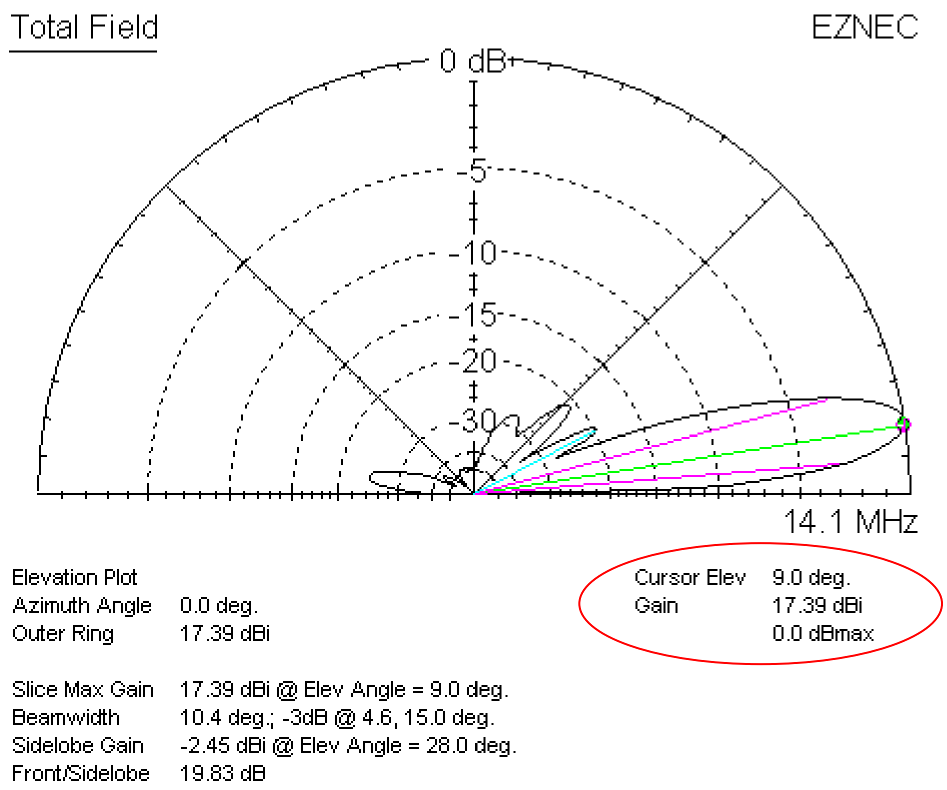
3.50dB stacking gain

Stacked 4 x 3-el yagi's

0.5, 1.0, 1.5 and 2.0 wavelength high, powers 1:2:2:1



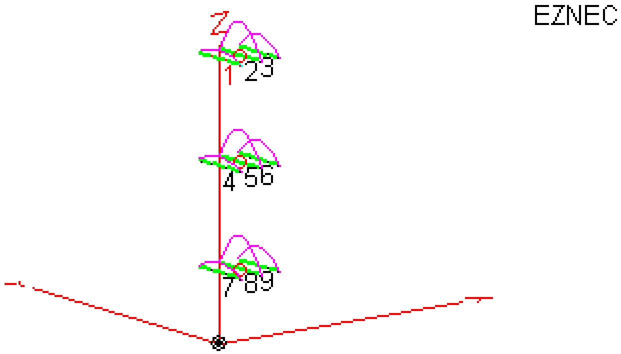
Average ground
5mS, Є=13



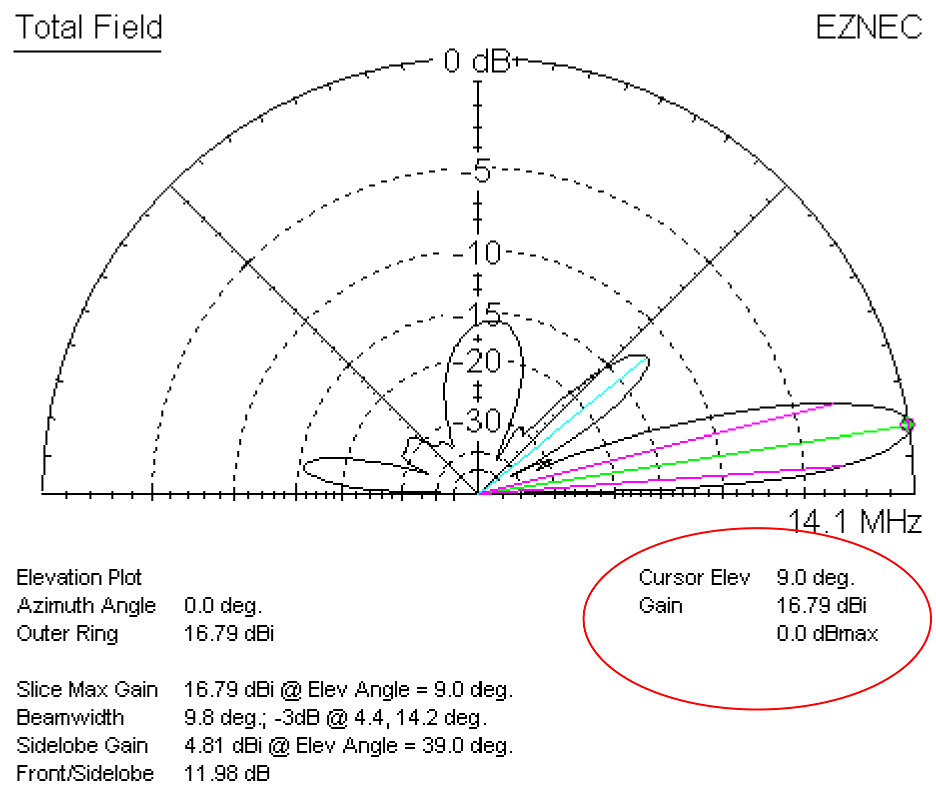
3.55dB stacking gain

Stacked 3 x 3-el yagi's

0.5, 1.25 and 2.0 wavelength high, powers 1:1:1



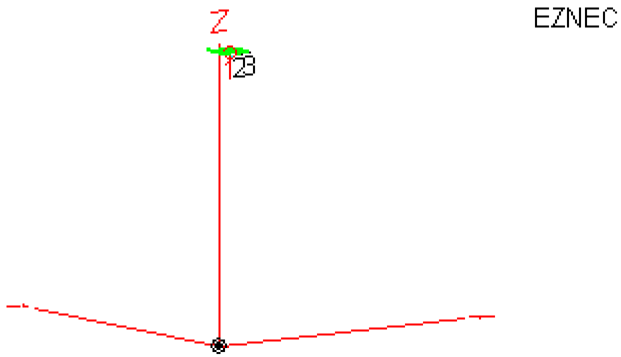
Average ground
5mS, Є=13



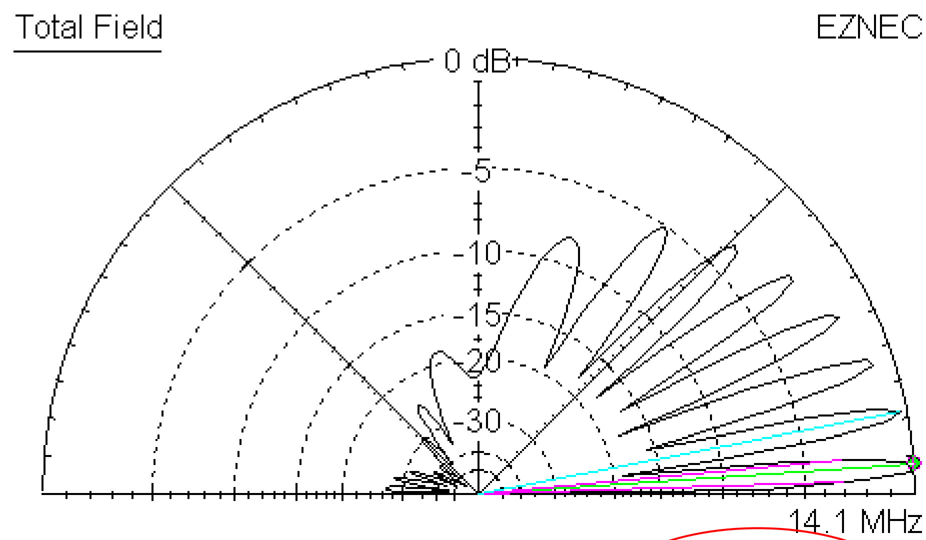
2.95dB stacking gain

3-el yagi's, up 84m

up 4.0 wavelength



Average ground
5mS, Є=13



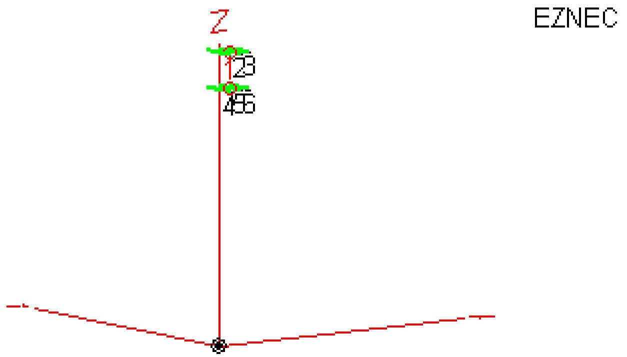
Elevation Plot	
Azimuth Angle	0.0 deg.
Outer Ring	13.88 dBi
Slice Max Gain	13.88 dBi @ Elev Angle = 4.0 deg.
Beamwidth	3.5 deg.; -3dB @ 1.8, 5.3 deg.
Sidelobe Gain	13.61 dBi @ Elev Angle = 11.0 deg.
Front/Sidelobe	0.27 dB

Cursor Elev	4.0 deg.
Gain	13.88 dBi
	0.0 dBmax

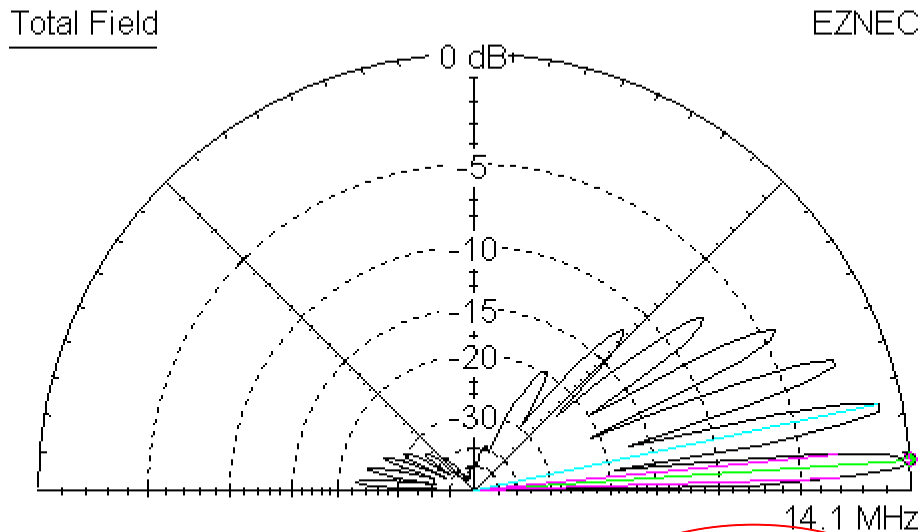
stacking gain reference

Stacked 2 x 3-el yagi's, highest up 84m

3.5 - 4.0 wavelength high in 0.5 wl steps, equal powers



Average ground
5mS, Є=13



Elevation Plot
Azimuth Angle 0.0 deg.
Outer Ring 16.57 dBi

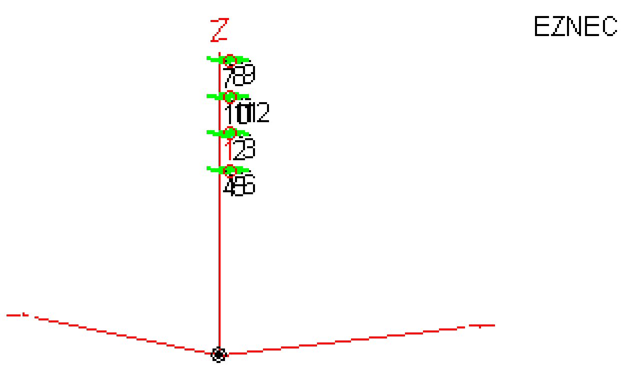
Cursor Elev 4.0 deg.
Gain 16.57 dBi
0.0 dBmax

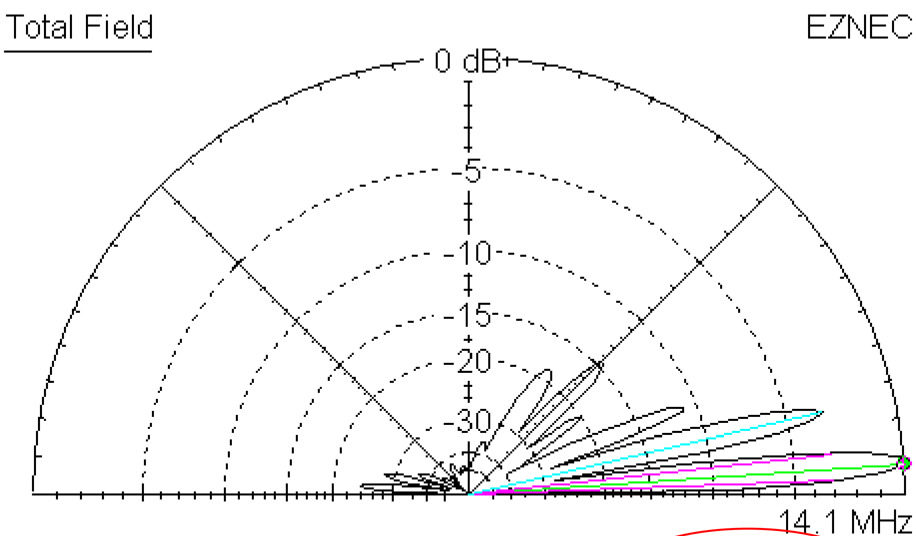
Slice Max Gain 16.57 dBi @ Elev Angle = 4.0 deg.
Beamwidth 3.8 deg.; -3dB @ 1.9, 5.7 deg.
Sidelobe Gain 15.63 dBi @ Elev Angle = 12.0 deg.
Front/Sidelobe 0.94 dB

2.68dB stacking gain

Stacked 4 x 3-el yagi's, highest up 84m

2.5 - 4.0 wavelength high in 0.5 wl steps, equal powers





Elevation Plot
Azimuth Angle 0.0 deg.
Outer Ring 19.11 dBi

Cursor Elev 4.0 deg.
Gain 19.11 dBi
0.0 dBmax

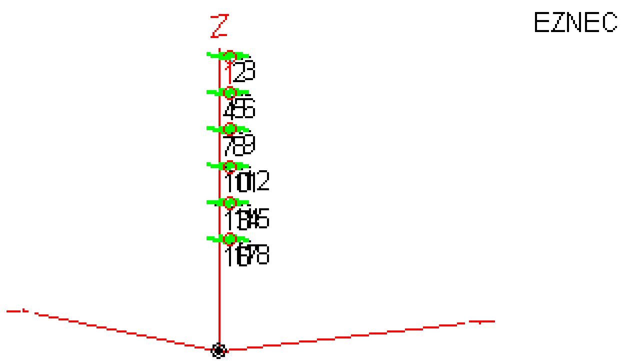
Slice Max Gain 19.11 dBi @ Elev Angle = 4.0 deg.
Beamwidth 4.3 deg.; -3dB @ 2.1, 6.4 deg.
Sidelobe Gain 15.96 dBi @ Elev Angle = 13.0 deg.
Front/Sidelobe 3.16 dB

Average ground
5mS, Є=13

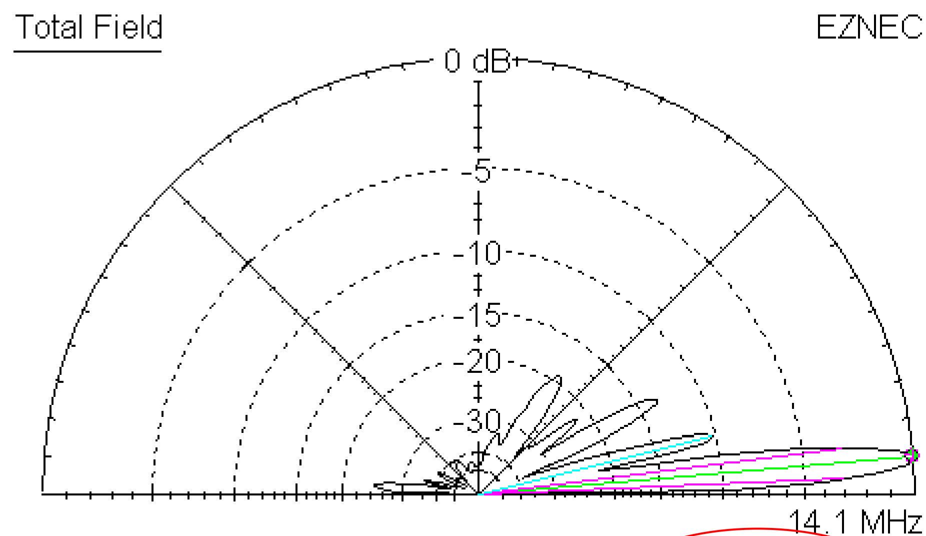
5.23dB stacking gain

Stacked 6 x 3-el yagi's, highest up 84m

1.5 - 4.0 wavelength high in 0.5 wl steps, equal powers



Average ground
5mS, Є=13



Elevation Plot	
Azimuth Angle	0.0 deg.
Outer Ring	20.16 dBi

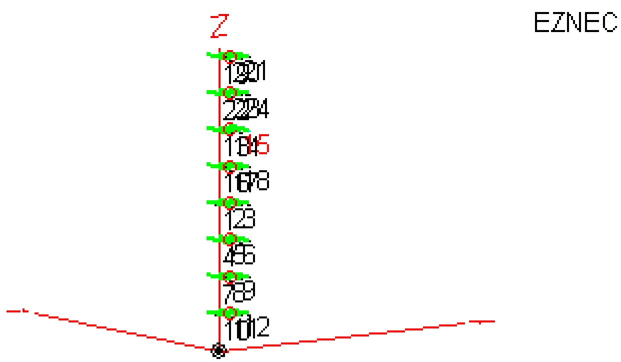
Cursor Elev	5.0 deg.
Gain	20.16 dBi
	0.0 dBmax

Slice Max Gain	20.16 dBi @ Elev Angle = 5.0 deg.
Beamwidth	4.9 deg.; -3dB @ 2.4, 7.3 deg.
Sidelobe Gain	10.0 dBi @ Elev Angle = 14.0 deg.
Front/Sidelobe	10.17 dB

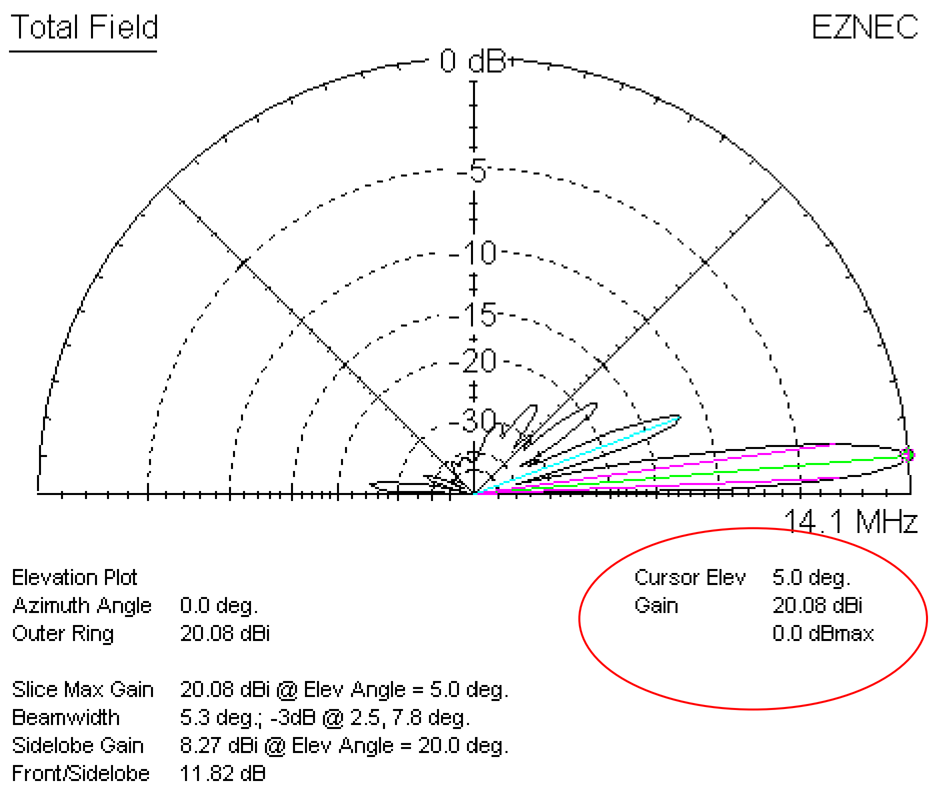
6.28dB stacking gain

Stacked 8 x 3-el yagi’s, highest up 84m

0.5 - 4.0 wavelength high in 0.5 wl steps, equal powers



Average ground
5mS, Є=13

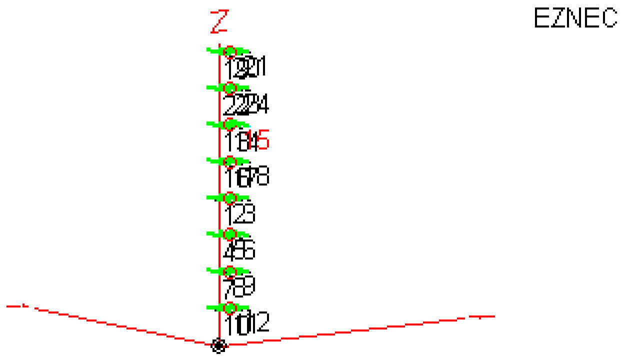


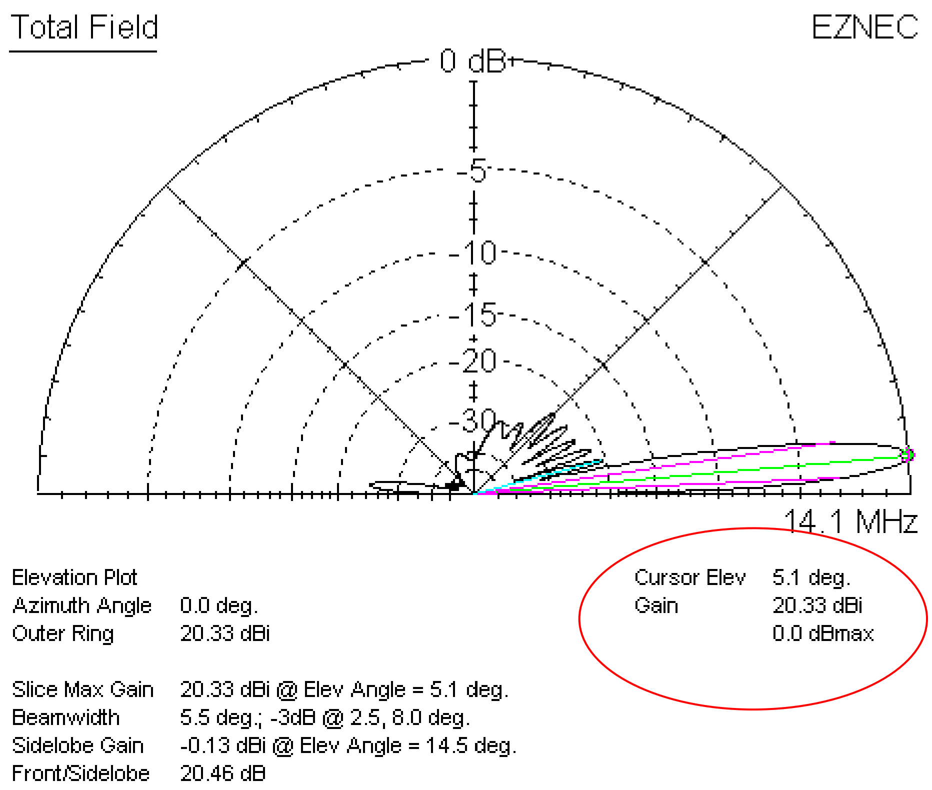
6.20dB stacking gain

Stacked 8 x 3-el yagi's, highest up 84m

0.5 - 4.0 wavelength high in 0.5 wl steps

tapered currents: 1/1/1.2/1.41/1.41/1.2/1/0.5





Average ground
5mS, Є=13

6.45dB stacking gain

5. Stacking horizontal antennas Conclusions:

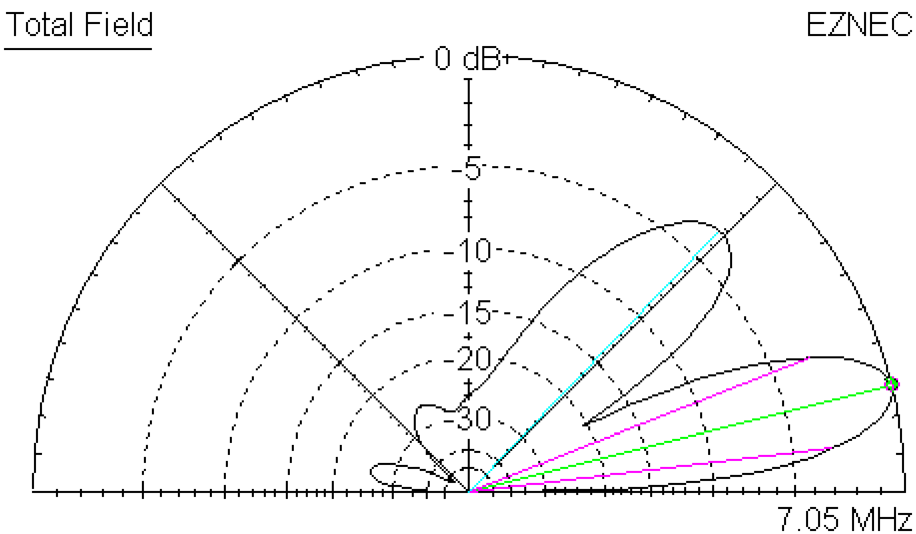
- Highest antenna dictates the take-off-angle TOA
- Ideal stacking distance is ½ wavelengths
- For best sidelobe attenuation all heights n x 0.5 x wavelength , n=1,2,.. are needed
- Stacking gain is generated by the highest 3/4 of antennas
  - The lowest 1/4 of antennas contribute mainly to sideloop attenuation
    - In very high stacks levels 0.5 and 1 lamda can be omitted
- Power tapering improves sidelobe attenuation with stacks of 3 and higher

6. Mutual coupling of different band antennas

How close can other band antennas be installed?

Influence to higher band

3-el 40m yagi, 42m high no other antennas

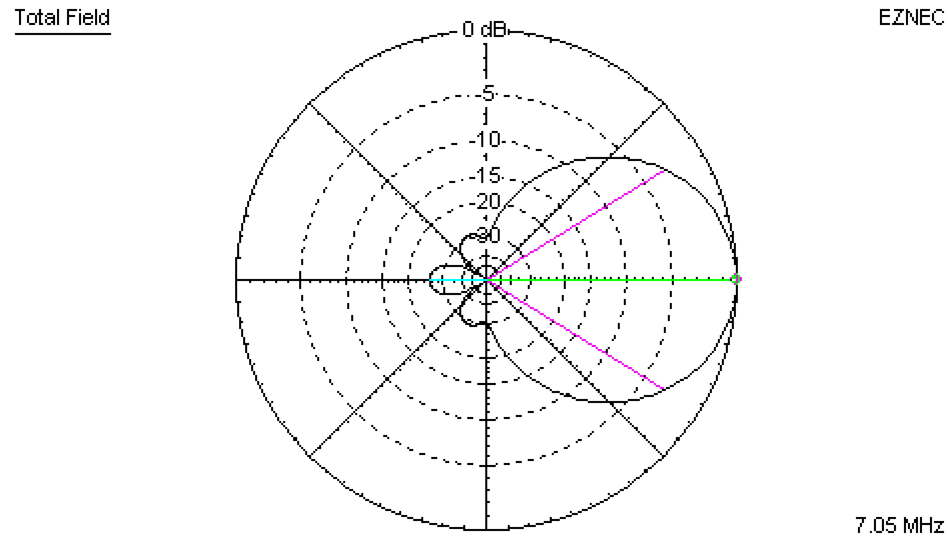


Elevation Plot
Azimuth Angle 0.0 deg.
Outer Ring 13.5 dBi

Cursor Elev 14.0 deg.
Gain 13.5 dBi
0.0 dBmax

Slice Max Gain 13.5 dBi @ Elev Angle = 14.0 deg.
Beamwidth 14.6 deg.; -3dB @ 6.8, 21.4 deg.
Sidelobe Gain 10.25 dBi @ Elev Angle = 46.0 deg.
Front/Sidelobe 3.25 dB

reference



Azimuth Plot
Elevation Angle 14.0 deg.
Outer Ring 13.5 dBi

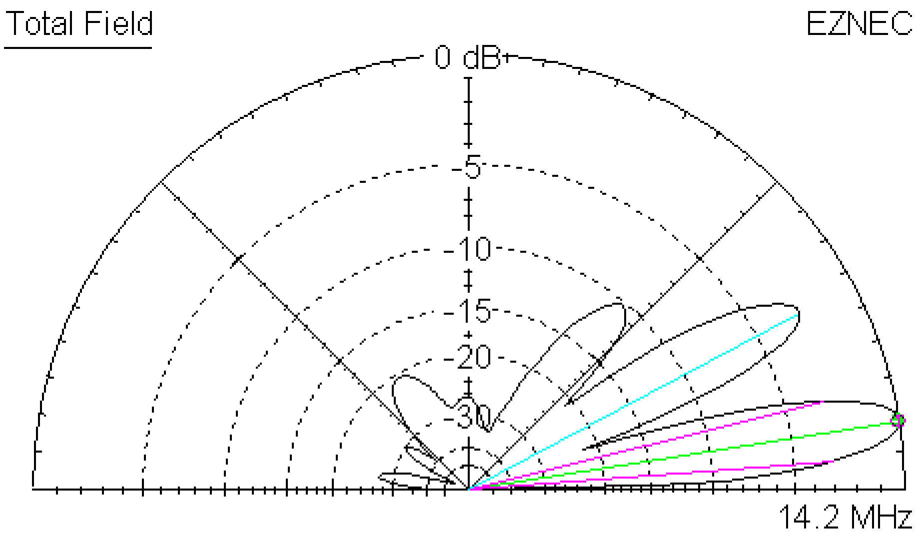
Cursor Az 0.0 deg.
Gain 13.5 dBi
0.0 dBmax

Slice Max Gain 13.5 dBi @ Az Angle = 0.0 deg.
Front/Back 25.37 dB
Beamwidth 63.2 deg.; -3dB @ 328.4, 31.6 deg.
Sidelobe Gain -11.87 dBi @ Az Angle = 180.0 deg.
Front/Sidelobe 25.37 dB

reference

Influence to higher band

4-el 20m yagi, 32m high, no other antennas

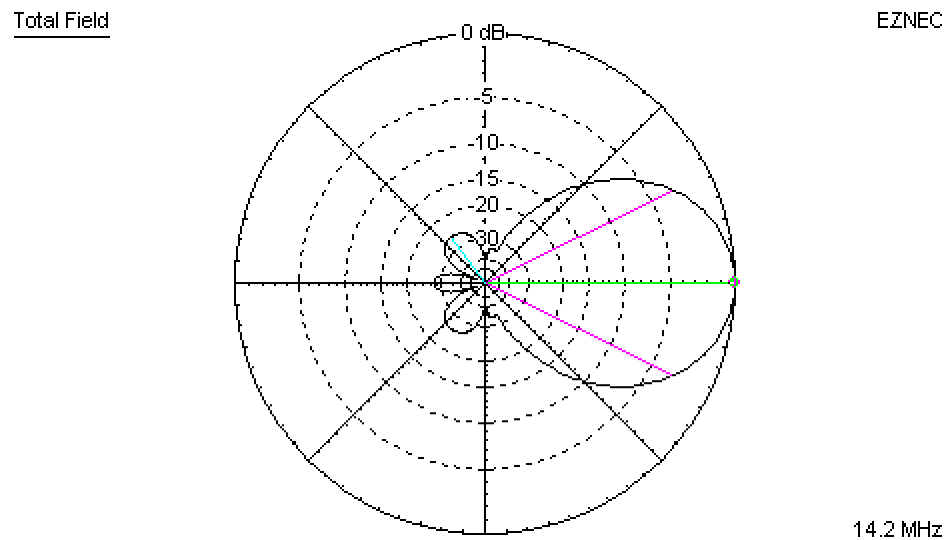


Elevation Plot
Azimuth Angle 0.0 deg.
Outer Ring 16.1 dBi

Cursor Elev 9.0 deg.
Gain 16.1 dBi
0.0 dBmax

Slice Max Gain 16.1 dBi @ Elev Angle = 9.0 deg.
Beamwidth 9.4 deg.; -3dB @ 4.5, 13.9 deg.
Sidelobe Gain 13.47 dBi @ Elev Angle = 28.0 deg.
Front/Sidelobe 2.63 dB

reference



Azimuth Plot
Elevation Angle 9.0 deg.
Outer Ring 16.1 dBi

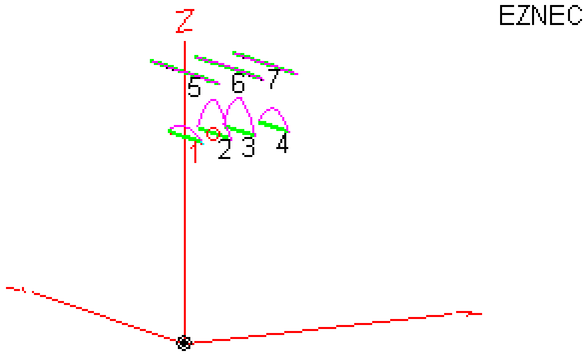
Cursor Az 0.0 deg.
Gain 16.1 dBi
0.0 dBmax

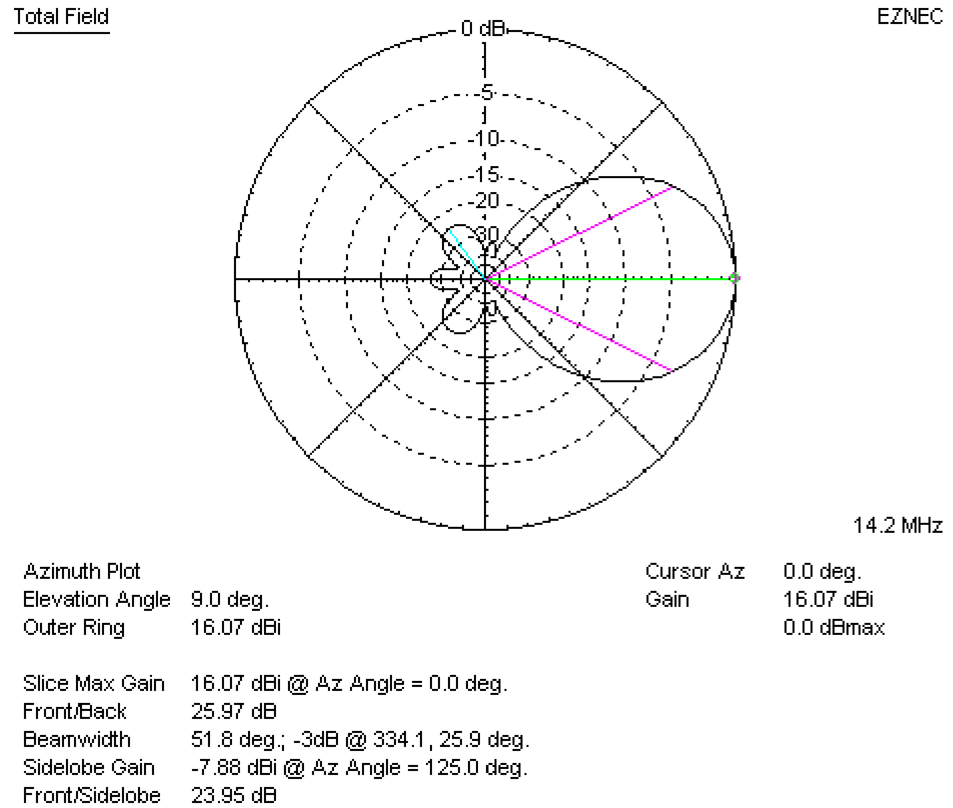
Slice Max Gain 16.1 dBi @ Az Angle = 0.0 deg.
Front/Back 27.28 dB
Beamwidth 52.2 deg.; -3dB @ 333.9, 26.1 deg.
Sidelobe Gain -9.27 dBi @ Az Angle = 127.0 deg.
Front/Sidelobe 25.38 dB

reference

Influence to higher band

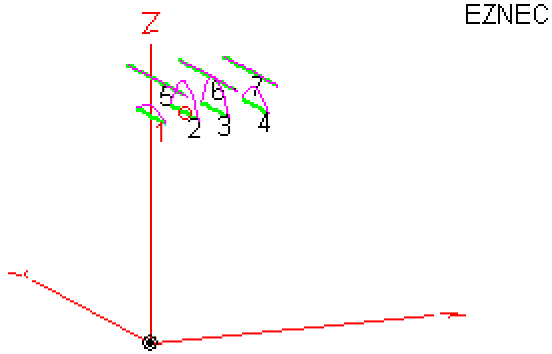
7050kHz@42m / 14200kHz@32m   10m dist

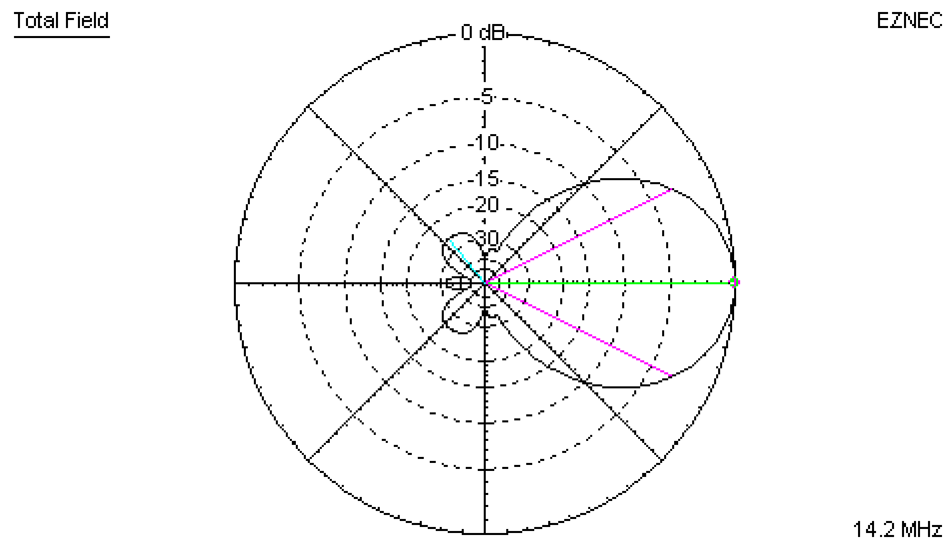




Influence to higher band

7050kHz@37m / 14200kHz@32m 5m dist



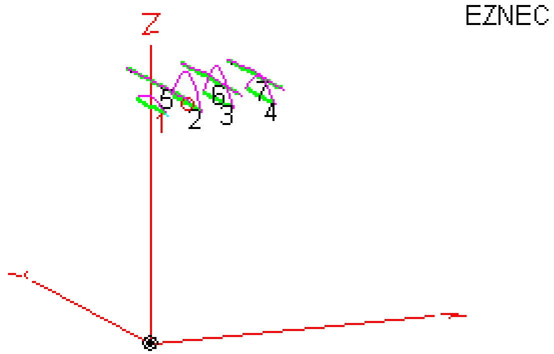


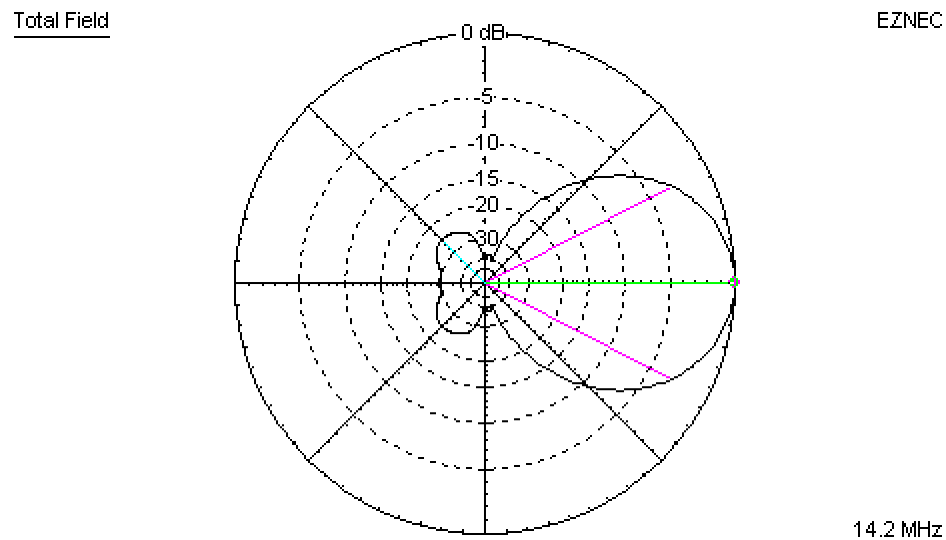
Azimuth Plot			Cursor Az	0.0 deg.
Elevation Angle	9.0 deg.		Gain	15.85 dBi
Outer Ring	15.85 dBi			0.0 dBmax

Slice Max Gain	15.85 dBi @ Az Angle = 0.0 deg.
Front/Back	31.85 dB
Beamwidth	52.6 deg.; -3dB @ 333.7, 26.3 deg.
Sidelobe Gain	-9.49 dBi @ Az Angle = 129.0 deg.
Front/Sidelobe	25.34 dB

Influence to higher band

7050kHz@35m / 14200kHz@32m 3m dist



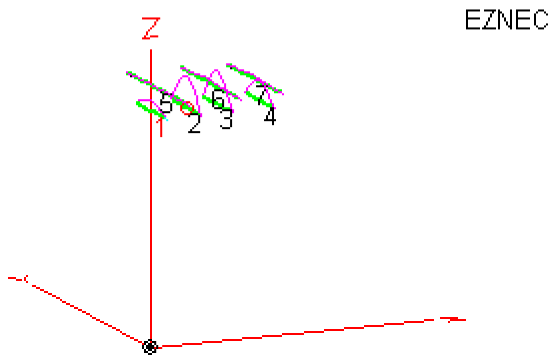


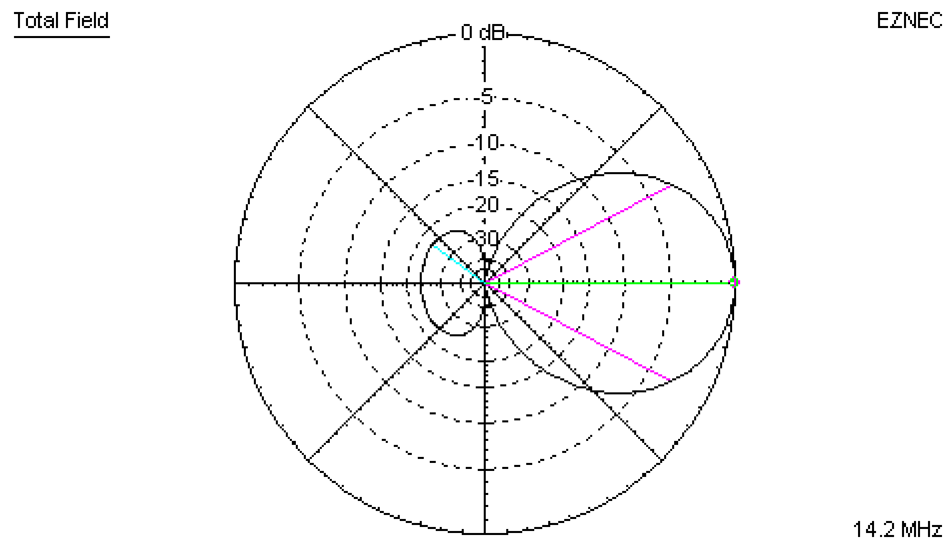
Azimuth Plot			Cursor Az	0.0 deg.
Elevation Angle	9.0 deg.		Gain	15.64 dBi
Outer Ring	15.64 dBi			0.0 dBmax

Slice Max Gain	15.64 dBi @ Az Angle = 0.0 deg.
Front/Back	29.27 dB
Beamwidth	54.4 deg.; -3dB @ 332.8, 27.2 deg.
Sidelobe Gain	-8.63 dBi @ Az Angle = 135.0 deg.
Front/Sidelobe	24.27 dB

Influence to higher band

7050kHz@34m / 14200kHz@32m   2m dist

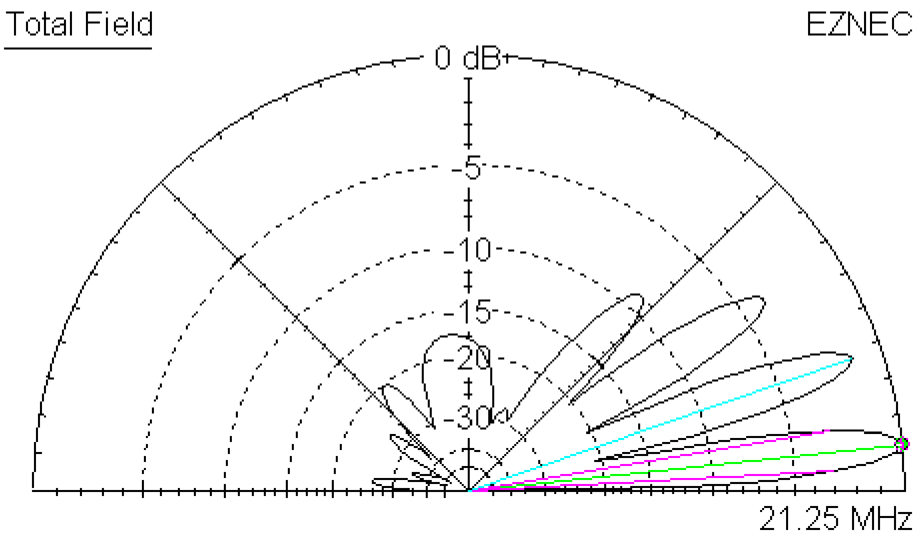




Azimuth Plot		Cursor Az	0.0 deg.
Elevation Angle	9.0 deg.	Gain	15.4 dBi
Outer Ring	15.4 dBi		0.0 dBmax

Slice Max Gain	15.4 dBi @ Az Angle = 0.0 deg.
Front/Back	23.29 dB
Beamwidth	56.2 deg.; -3dB @ 331.9, 28.1 deg.
Sidelobe Gain	-7.69 dBi @ Az Angle = 144.0 deg.
Front/Sidelobe	23.09 dB

4-el 21250kHz@32m, no other antennas

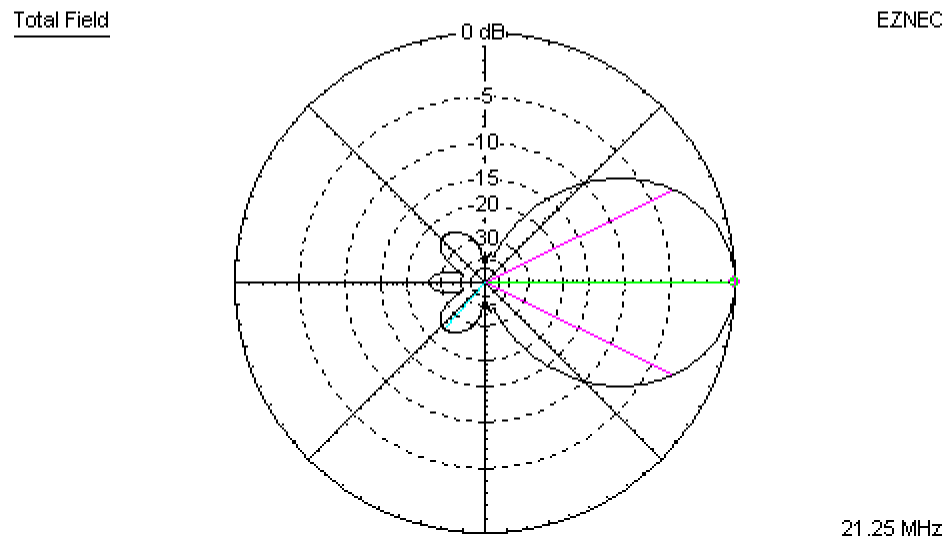


Elevation Plot
Azimuth Angle 0.0 deg.
Outer Ring 16.24 dBi

Cursor Elev 6.0 deg.
Gain 16.24 dBi
0.0 dBmax

Slice Max Gain 16.24 dBi @ Elev Angle = 6.0 deg.
Beamwidth 6.2 deg.; -3dB @ 3.1, 9.3 deg.
Sidelobe Gain 14.97 dBi @ Elev Angle = 19.0 deg.
Front/Sidelobe 1.26 dB

reference



Azimuth Plot
Elevation Angle 6.0 deg.
Outer Ring 16.24 dBi

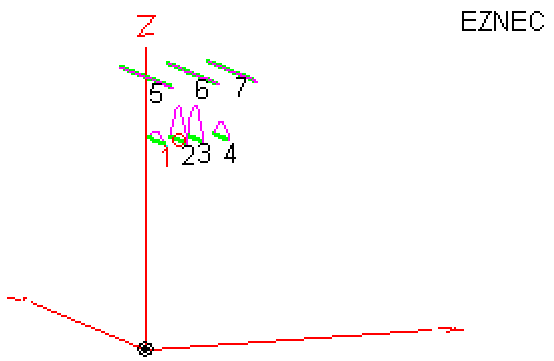
Cursor Az 0.0 deg.
Gain 16.24 dBi
0.0 dBmax

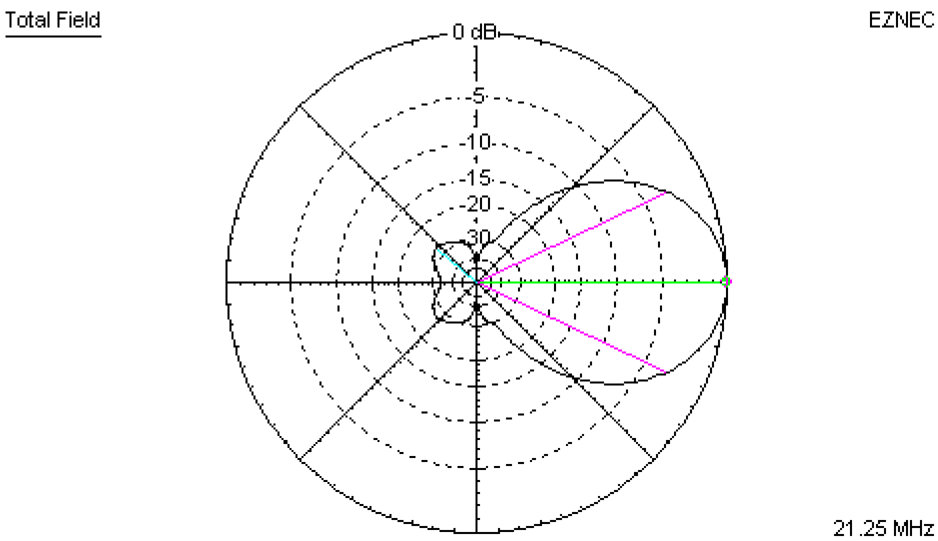
Slice Max Gain 16.24 dBi @ Az Angle = 0.0 deg.
Front/Back 25.73 dB
Beamwidth 52.2 deg.; -3dB @ 333.9, 26.1 deg.
Sidelobe Gain -7.71 dBi @ Az Angle = 229.0 deg.
Front/Sidelobe 23.95 dB

reference

Influence to higher band

7050kHz @42m / 21250kHz@32m 10m dist





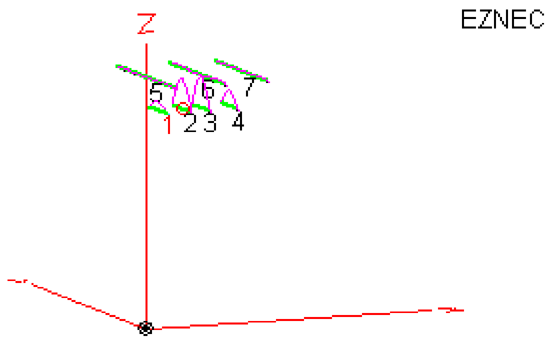
Azimuth Plot
Elevation Angle 6.0 deg.
Outer Ring 16.57 dBi

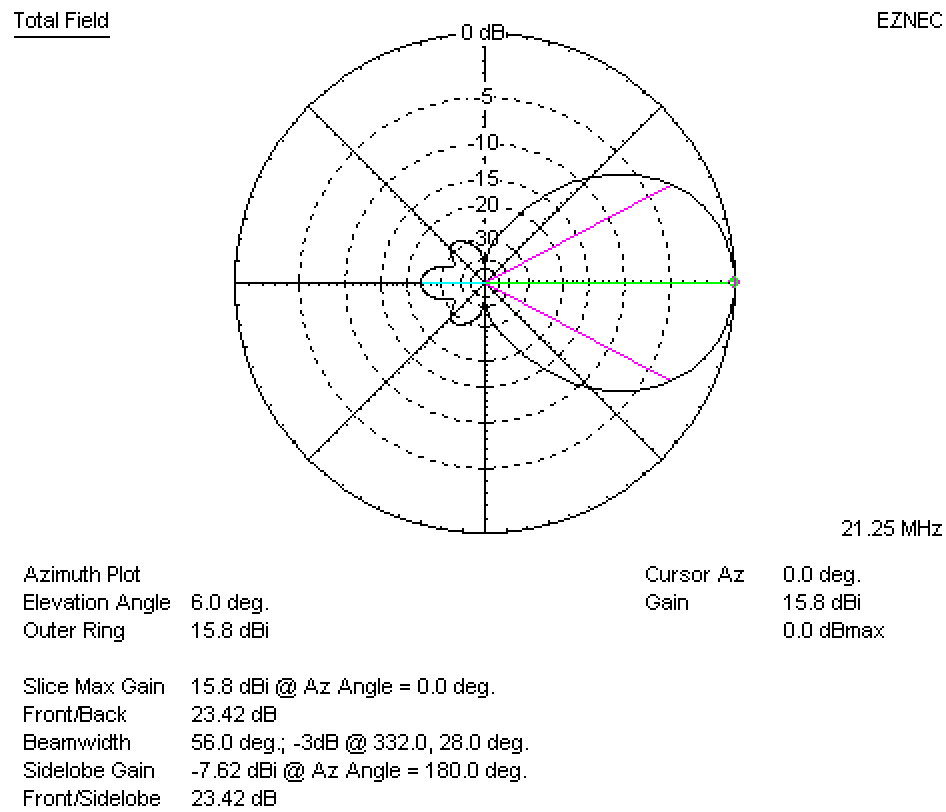
Cursor Az 0.0 deg.
Gain 16.57 dBi
0.0 dBmax

Slice Max Gain 16.57 dBi @ Az Angle = 0.0 deg.
Front/Back 33.44 dB
Beamwidth 50.8 deg.; -3dB @ 334.6, 25.4 deg.
Sidelobe Gain -10.2 dBi @ Az Angle = 139.0 deg.
Front/Sidelobe 26.77 dB

Influence to higher band

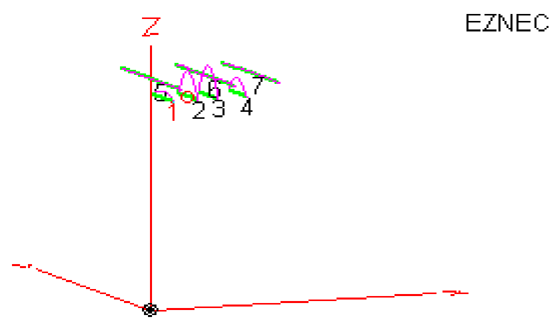
7050kHz @37m / 21250kHz@32m   5m dist

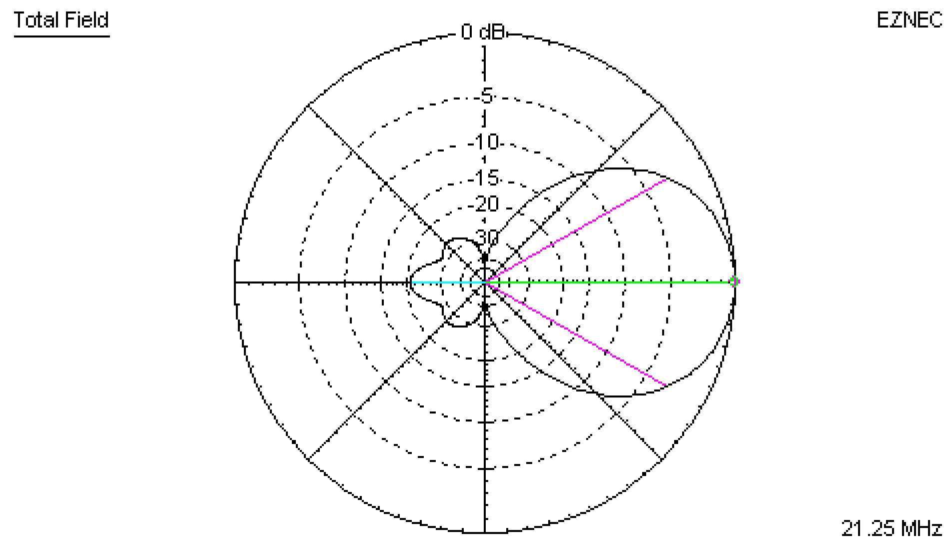




Influence to higher band

7050kHz @35m / 21250kHz@32m   3m dist



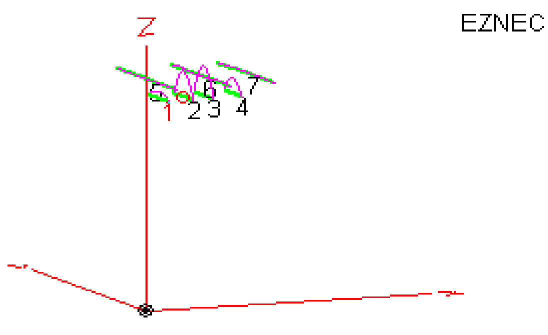


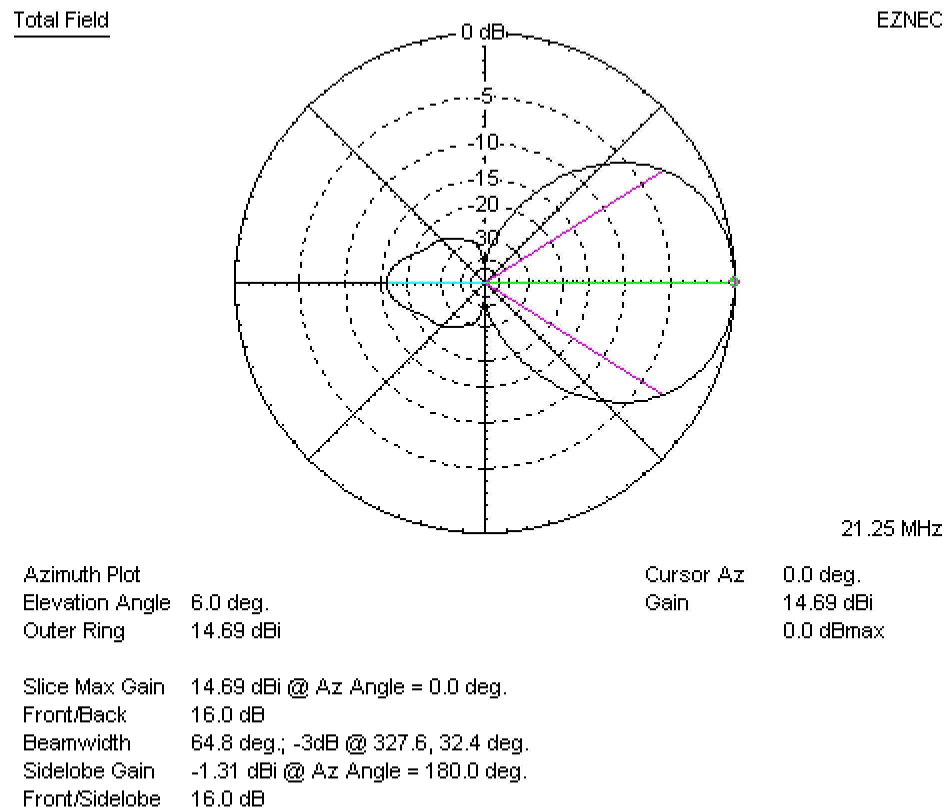
Azimuth Plot		Cursor Az	0.0 deg.
Elevation Angle	6.0 deg.	Gain	15.25 dBi
Outer Ring	15.25 dBi		0.0 dBmax

Slice Max Gain	15.25 dBi @ Az Angle = 0.0 deg.
Front/Back	20.79 dB
Beamwidth	59.6 deg.; -3dB @ 330.2, 29.8 deg.
Sidelobe Gain	-5.54 dBi @ Az Angle = 180.0 deg.
Front/Sidelobe	20.79 dB

Influence to higher band

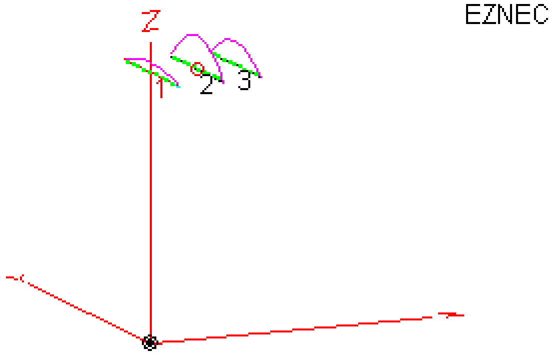
7050kHz @34m / 21250kHz@32m 2m dist

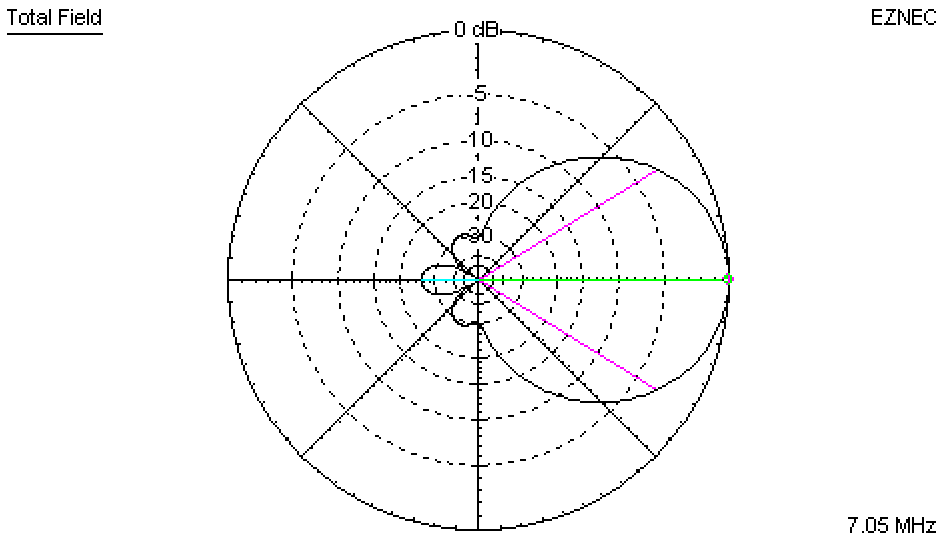




Influence to lower band

3-el yagi 7050kHz@42m, no other antennas





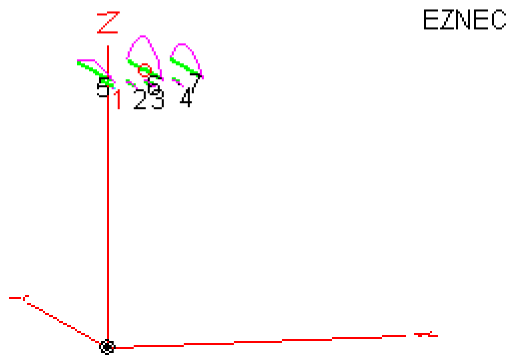
Azimuth Plot
Elevation Angle 14.0 deg.
Outer Ring 13.5 dBi

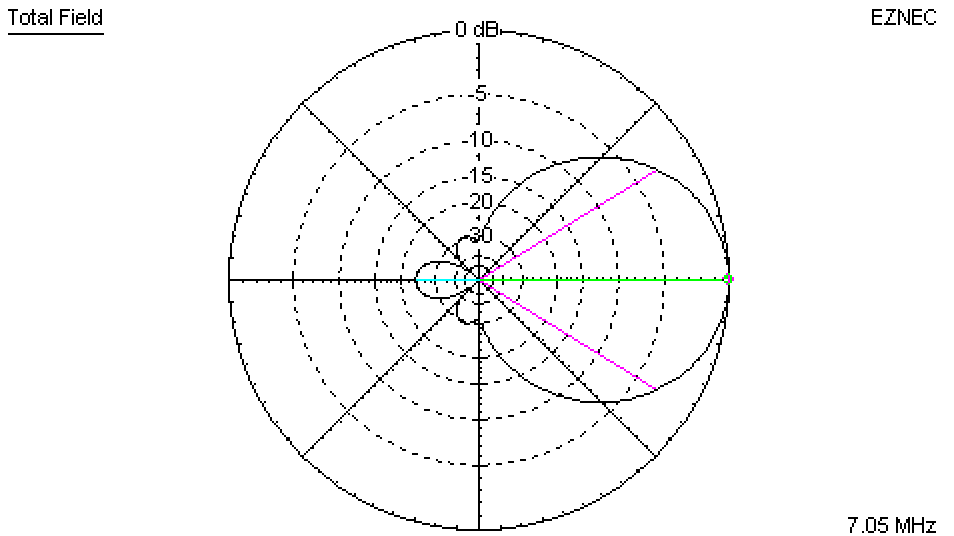
Cursor Az 0.0 deg.
Gain 13.5 dBi
0.0 dBmax

Slice Max Gain 13.5 dBi @ Az Angle = 0.0 deg.
Front/Back 25.37 dB
Beamwidth 63.2 deg.; -3dB @ 328.4, 31.6 deg.
Sidelobe Gain -11.87 dBi @ Az Angle = 180.0 deg.
Front/Sidelobe 25.37 dB

Influence to lower band

7050kHz @42m / 21250kHz@40m 2m dist





Azimuth Plot
Elevation Angle 14.0 deg.
Outer Ring 13.49 dBi

Cursor Az 0.0 deg.
Gain 13.49 dBi
0.0 dBmax

Slice Max Gain 13.49 dBi @ Az Angle = 0.0 deg.
Front/Back 23.56 dB
Beamwidth 63.0 deg.; -3dB @ 328.5, 31.5 deg.
Sidelobe Gain -10.07 dBi @ Az Angle = 180.0 deg.
Front/Sidelobe 23.56 dB

6. Mutual coupling of different bands Conclusions:

- Lower band suffers very little, even when spacing is 0.05 lamda
- Higher band lose gain and F/B when lower band antenna is too close
  - With distances less than 0.5 lamda there is a risk for losing performance
  - In the example of 20/40m 0.15 lamda was about the limit
  - In the example of 15/40m 0.3 lamda was about the limit

- Every case should be studied separately, it is impossible to give accurate guidance