Low band receiving antennas

Contest University 7.7.2017

http://www.kolumbus.fi/pekka.ketonen/Lowband RX-antennas.pdf

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The goal of this presentation

- To introduce the key parameters which define performance of receiving antennas
- To compare performance of different receiving antennas and support this way your decision making
- This is not a collection of construction instructions

Content

Concepts and requirements

A. Angle of arrival

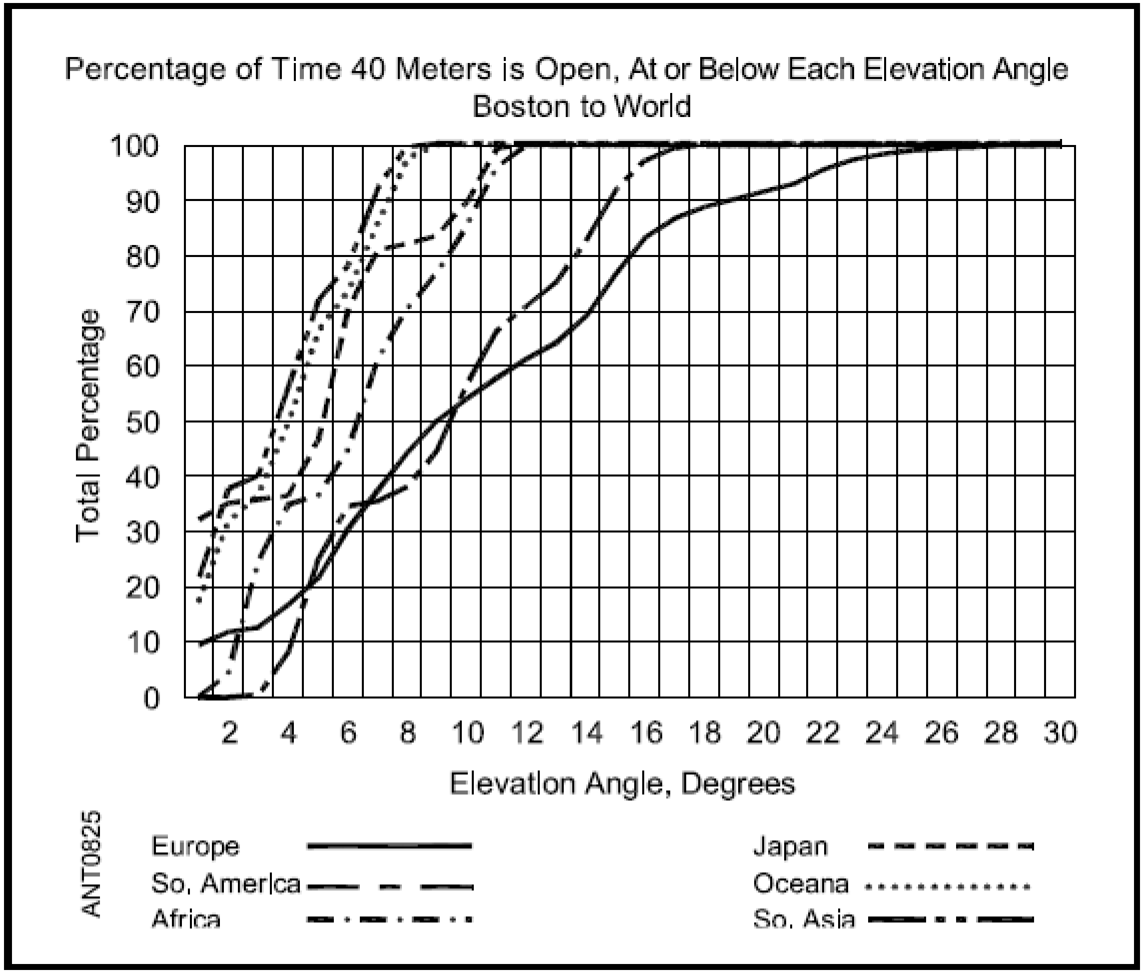


Figure 4.30 — The cumulative distribution function showing the total percentage of time that 40 meters is open, at or below each elevation angle, from Boston to the world. For example, 50% of the time the band is open to Europe from Boston, it is at 10° or less. The angles for DX work are indeed low.

Angle of arrival

Example: **40m band in** Boston:

<u>All DX-stations arrive at 25 degree elevation or less.</u>

<u>50% of the time they arrive at 10deg or less.</u>

Some continents arrive always at 9deg or less

Situation here in OH is quite the same.

Source:ARRL Antenna Hanbook

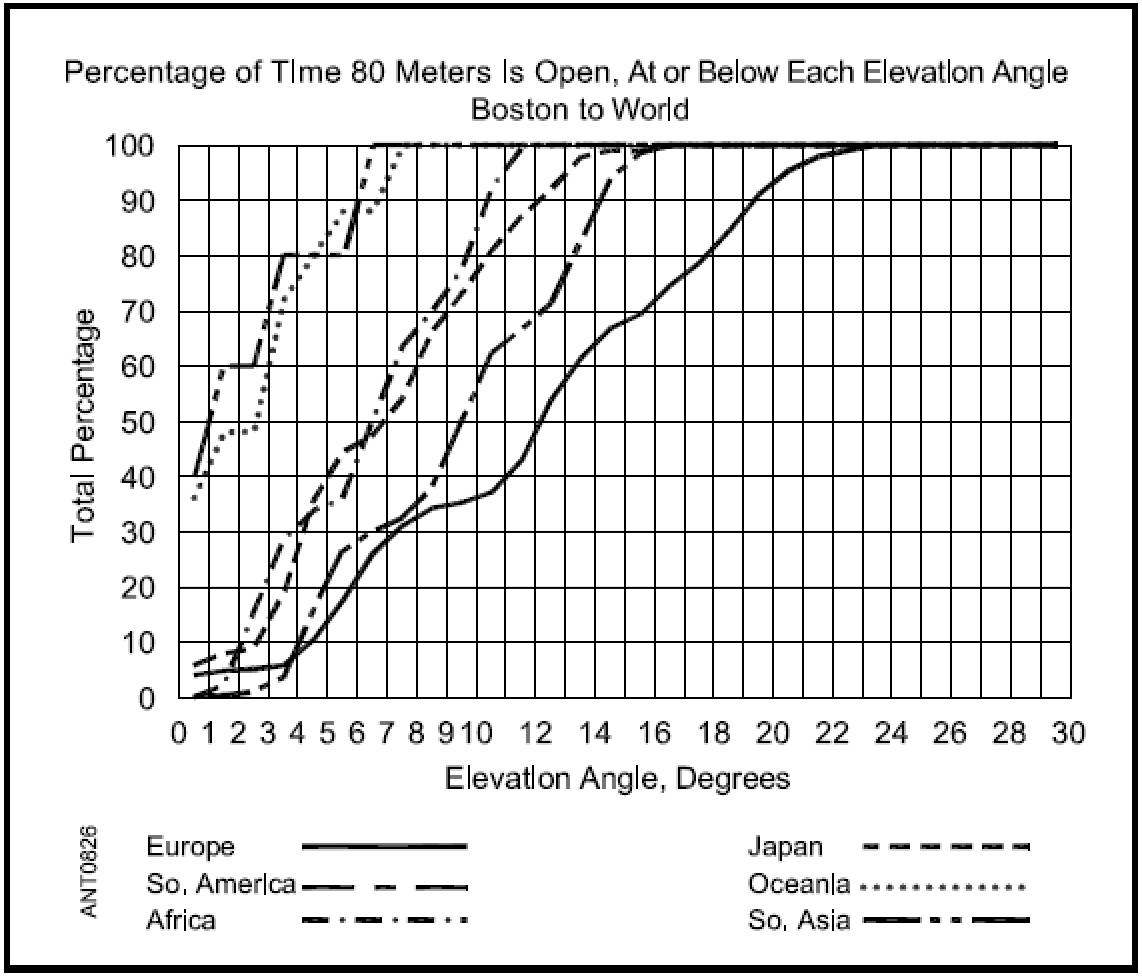


Figure 4.31 — The cumulative distribution function showing the total percentage of time that 80 meters is open, at or below each elevation angle, from Boston to the world. For example, 50% of the time the band is open to Europe from Boston, it is at 13° or less.

Angle of arrival

Example: **80m band** in Boston area:

<u>All DX-stations arrive at 23deg elevation or less.</u>

<u>50% of the time they arrive at 12deg or less.</u>

Some continents arrive always at 10deg or less.

Situation here in OH is quite the same.

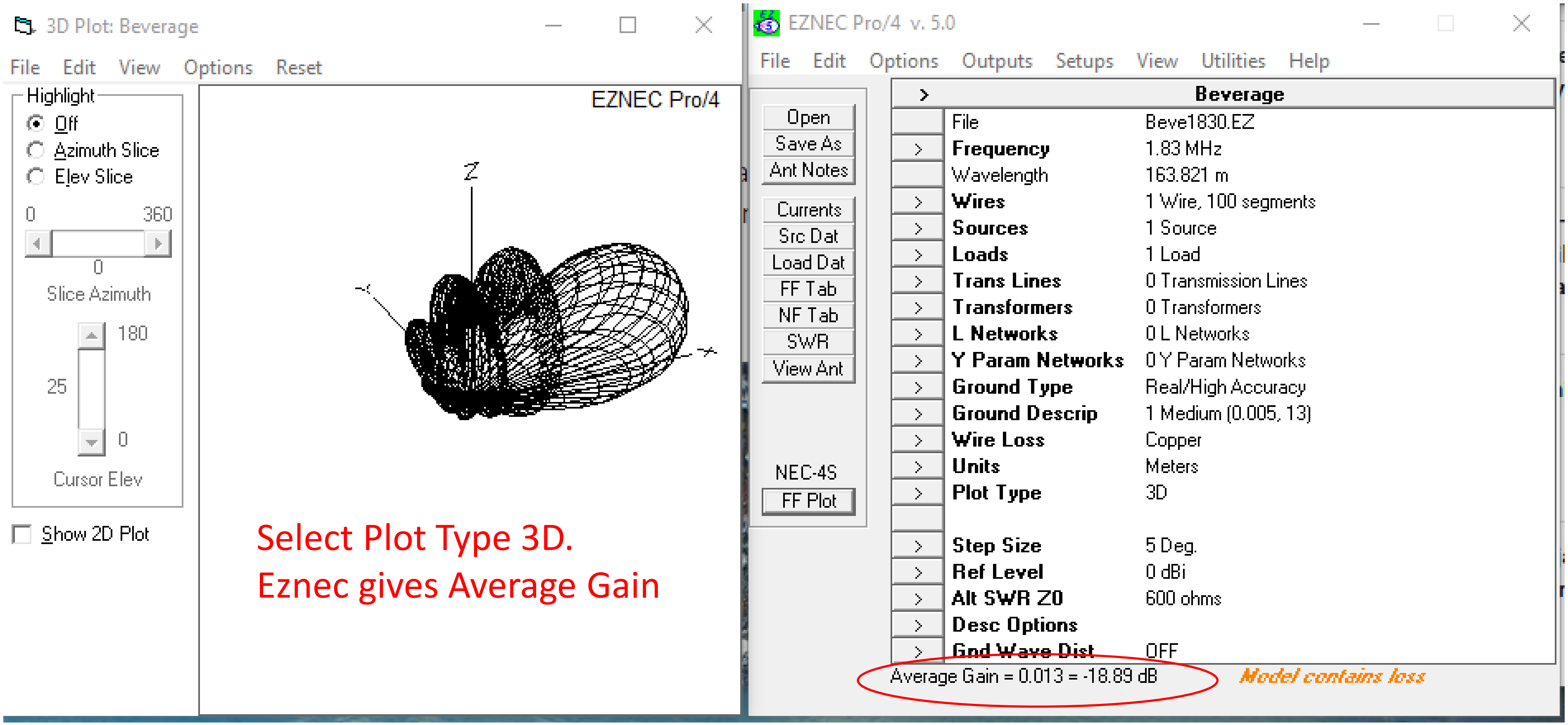
Source:ARRL Antenna Hanbook

B. Directivity

Directivity, gain and efficiency

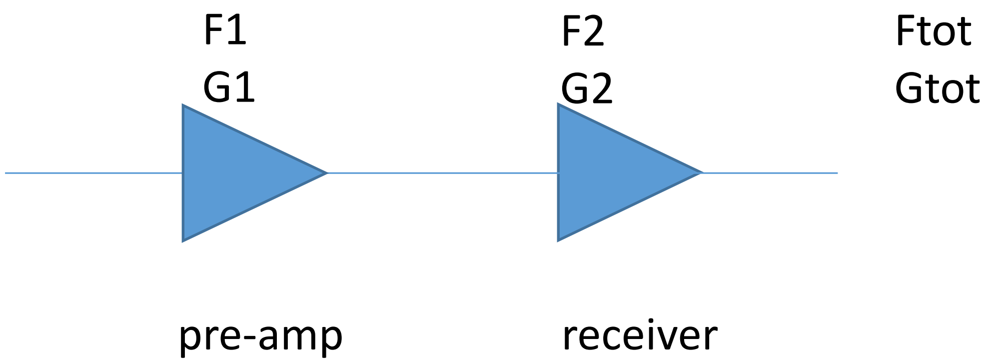
- Antenna gain is: its max gain in the main beam, divided by the gain of an isotropic antenna. The result is given in dBi.
- Directivity (RDF) is the ratio between the gain of the main beam and the average gain of an antenna
  - **Directivity = Max gain – Average gain**, when measured in dB
- Average gain of a lossless antenna is 0dbi
- Average gain is less than 0dBi, if antenna has losses
  - **Gain = Directivity x Efficiency** (absolute numbers)
  - **Efficiency = Average gain**
- In receiving antennas Directivity is most important. Efficiency can be compromised. Antenna gain can be even negative in dBi

Average gain – calculation with Eznec



C. Noise in receiving

Cascaded Noise Figure, typical application



F= noise figure
G=gain

Ftot = F1 + (F2-1)/G1, with absolute values, not dB

Cascaded Noise Figure, in this case

F1
G1

F2
G2

Ftot
Gtot

F= noise figure
G=gain

F1 = atmospheric noise figure
G1 =waste margin
F2 = RX noise figure (or pre-amp)

Ftot = F1 + (F2-1)/G1, with absolute values, not dB

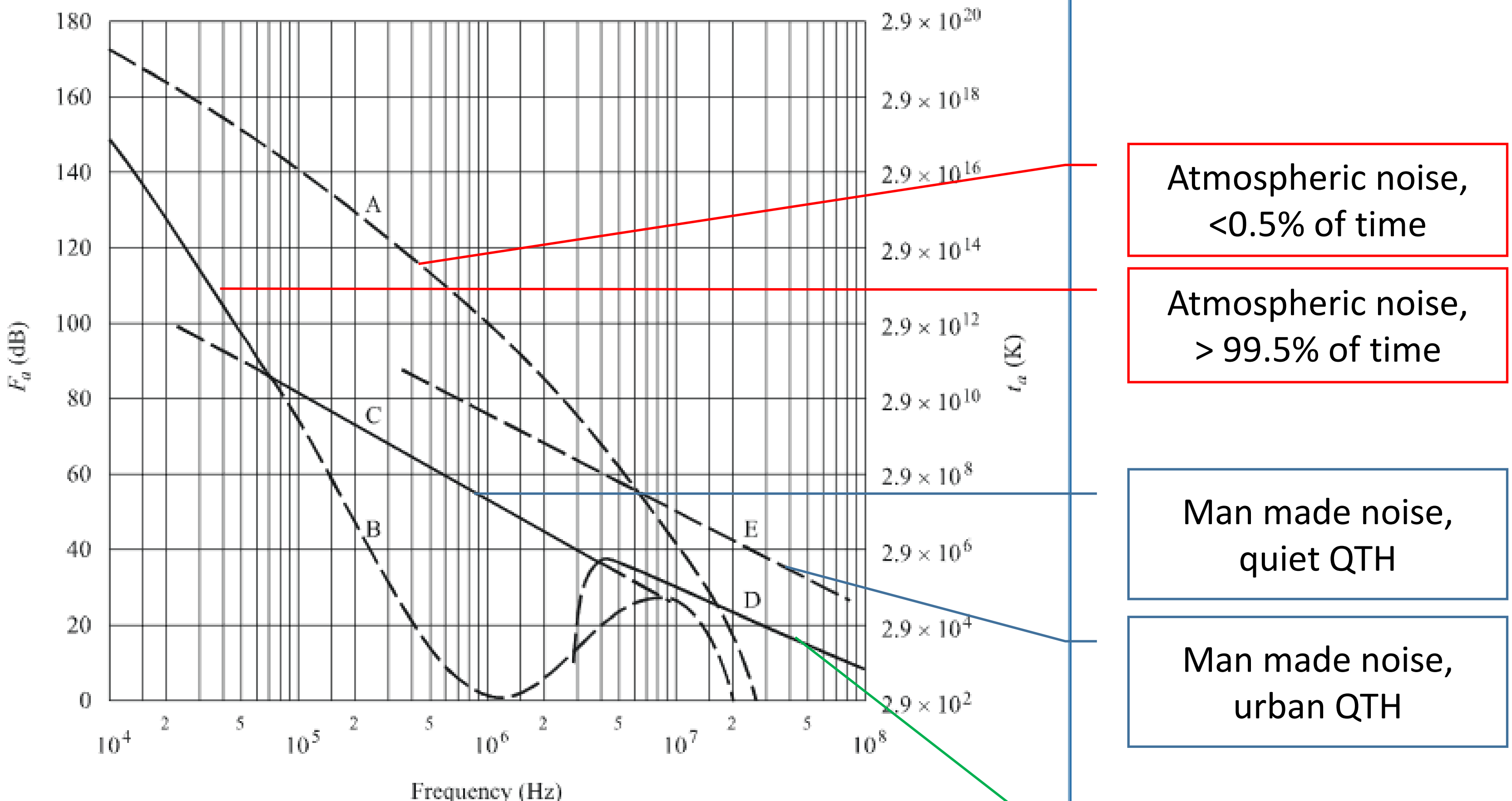
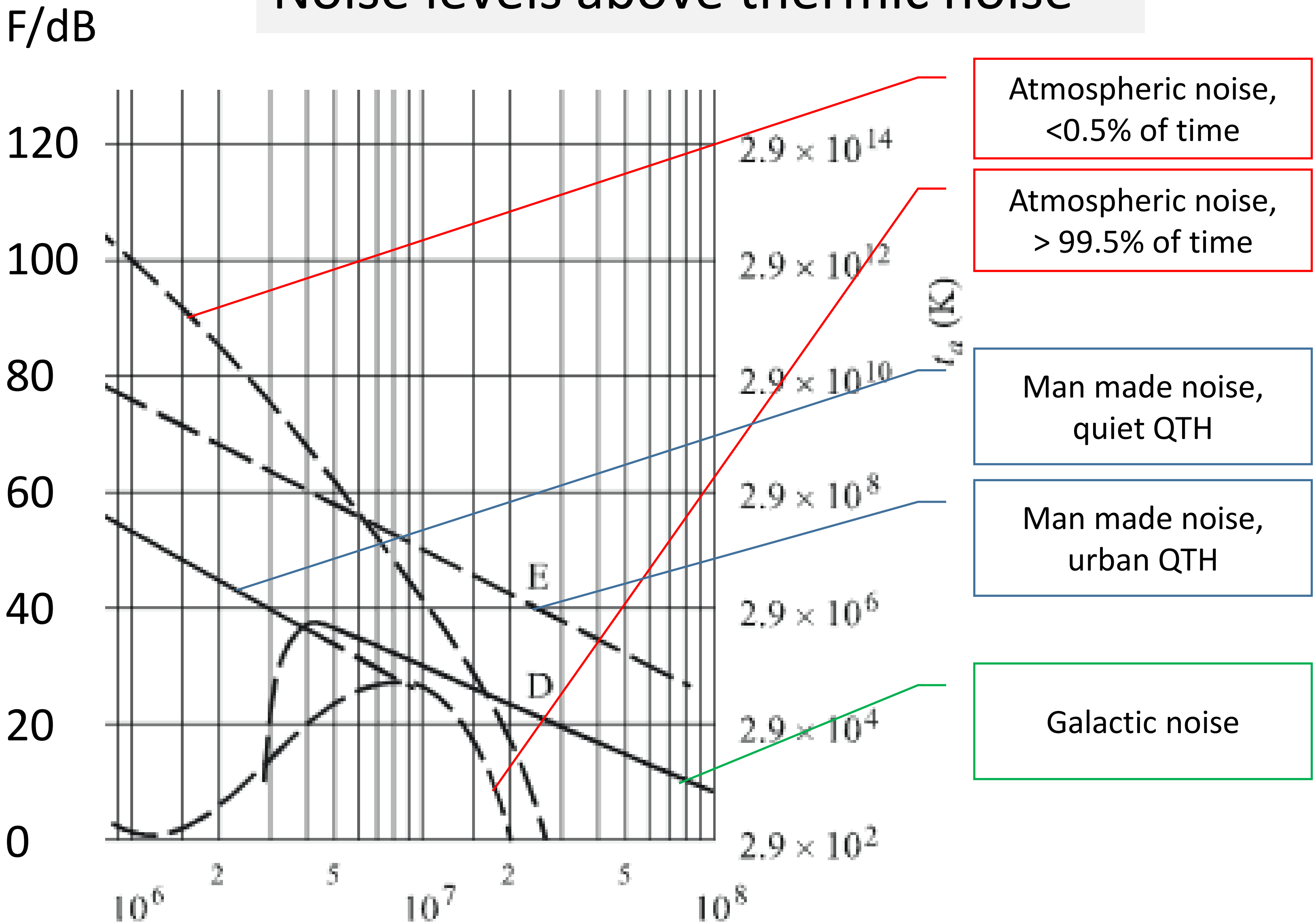
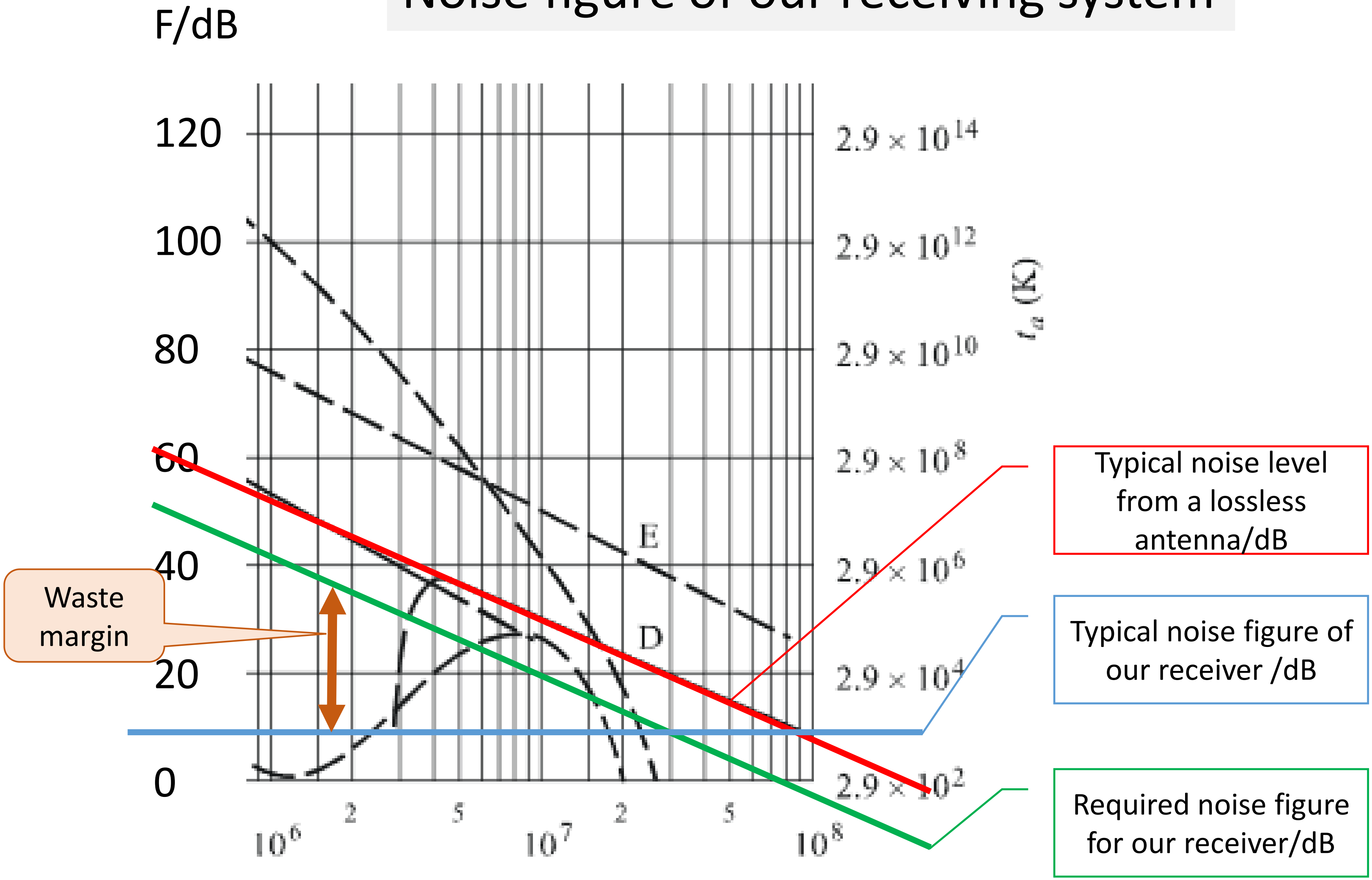


FIGURE 1: Noise Figure in dB above the reference noise temperature, 290K (17°C). A – atmospheric noise, value exceeded 0.5% of the time. B - atmospheric noise, value exceeded 99.5% of the time. C – man-made noise, quiet receiving site. D – Galactic noise. E – median city area man-made noise. The solid line indicates the minimum noise level expected. (Source: ITU-R Recommendation P.372-10 (10/2009), used with permission).

Noise levels above thermic noise



Noise figure of our receiving system



Requirements for our total noise figure

- If our receiving system has 10dB better noise figure than the radio spectrum, we get everything out of it. Our system adds only small amount of noise, +0.3dB.
- In such a case **total noise figure requirement** for our receiving system, **radio + antenna + cables + filters,** in a quiet QTH are:
  - F=10dB @30MHz
  - F=13dB @20MHz
  - F=20dB @ 10MHz
  - F=23dB @ 7MHz
  - F=27dB @3.7MHz
  - F=36dB @ 1.85MHz
- As receiver noise figure typically is 10dB on HF we can waste on 160m 26dB in poor antenna efficiency, cable loss or so, without loosing in S/N performance.

Waste margin, when **receiver noise figure is 10dB**

Frequency /MHz	Needed noise figure /dB	Waste margin/dB
30	10	**0**
20	13	**-3**
10	20	**-10**
7	23	**-13**
3.5	27	**-17**
1.85	36	**-26**

antenna + cables + filters

Waste margin, when antenna **preamplifier noise figure is 3dB** and gain high enough, >20dB

Frequency /MHz	Needed noise figure /dB	Waste margin/dB
30	10	**-7**
20	13	**-10**
10	20	**-17**
7	23	**-20**
3.5	27	**-24**
1.85	36	**-33**

antenna + cables + filters

What number to use in Waste Margin?

- **Average gain + cable loss + filter loss**(all negative dB-values)
  - Average gain illustrates our antennas capability to receive noise, which arrives from all around
  - Max gain illustrates our antennas capability to receive the wanted signal from a certain direction
- We use average gain–value when filling our waste margin, plus cable loss, filter loss..
  - If preamplifier is used at the antenna feed point and amp gain is high enough (>20dB), losses after preamp are meaningless
- *See an example, DHDL-antenna*

Example: Noise critical situation with DHDL on 160m

Ftot = F1 + (F2-1)/G1, with absolute values, not dB

MHz	F1/dB	G1/dB	F2/dB	Ftot/dB		
1.85	46	**-33**	3	46.21		Waste margin = G1
1.85	46	**-38.3**	3	**46.68**		G1=DHDL @ average gain
1.85	46	-38.3	2	46.41		
1.85	46	-38.3	1	46.19		
1.85	46	-38.3	0	46.00		Impossible

Band noise figure F1=46dB @1.85MHz
Preamp noise figure F2=3dB, gain>20dB
DHDL average gain G1=-38.3dBi

> S/N degrease by 0.68dB

Summary

Summary of antennas analyzed.

More details later in the presentation.

Antenna	Max dimension	Frequency	Max gain	Average gain	Directivity
¼ wave GP	Radials 20m	3.8MHz	0.31dBi@22deg	-5.07dBi	5.38dB
2-Yagi, full size	Up 41m	3.53MHz	11.46@27deg	-0.86dBi	12.32dB
1x Beverage 80m	200m	3.8MHz	-4.24dBi@24deg	-17.8dBi	13.56dB
Beverage 160m	415m	1.83MHz	-5.35dBi@23deg	-18.89dBi	13.54dB
2x Beverage 80m	**20**x200m	3.8MHz	-1.3dBi@24deg	-15.08dBi	13.8dB
2x Beverage 80m	**40**x200m	3.8MHz	-1.17dBi@24deg	-15.83dBi	14.66dB
2x Beverage 80m	**50**x200m	3.8MHz	-1.18dB@24deg	-16.33dBi	15.15dB
2x Beverage 80m	**60**x200m	3.8MHz	-1.2dBdB@24deg	-16.81dBi	15.61dB
K9AY loop	10m	1.83MHz	-25.56dBi@31deg	*-33.25dBi*	7.7dB
Flag	10m	1.83MHz	-27.54dBi@31deg	*-35.3dBi*	7.76dB
EWE	15m	1.82MHz	-22.63dBi@34deg	*-30.26dBi*	7.6dB
DHDL	22m	1.8MHz	-28.48dBi@23deg	*-38.32dBi*	9.84dB
DHDL	22m	3.8MHz	-11.63dBi@31deg	*-20.59dBi*	8.96dB

Pre-amp not enough
Pre-amp needed

Antenna	Max dimension	Frequency	Max gain	Directivity
2 phased verticals	25m	1.83MHz	r @23deg	9.08dB
3 verticals in line	24m	3.5MHz	r @20.4deg	12.31dB
4 verticals in line	36m	3.5MHz	r @ 18deg	14.12dB
RX-4SQ	15x15m	3.79MHz	r @23deg	11.12dB
RX-4SQ	20x20m	1.83MHz	r @21deg	11.28dB
8 circle array	radius 30.5m	1.83MHz	r @19.8deg	13.37dB
Magnetic loop	2m	3.7MHz	-3.72dBi @ 90deg	5.7dB
Low dipole	80m @20m	1.83MHz	6.37dBi @ 90deg	8.3dB

r

In vertical arrays a pre-amp is used at each element.

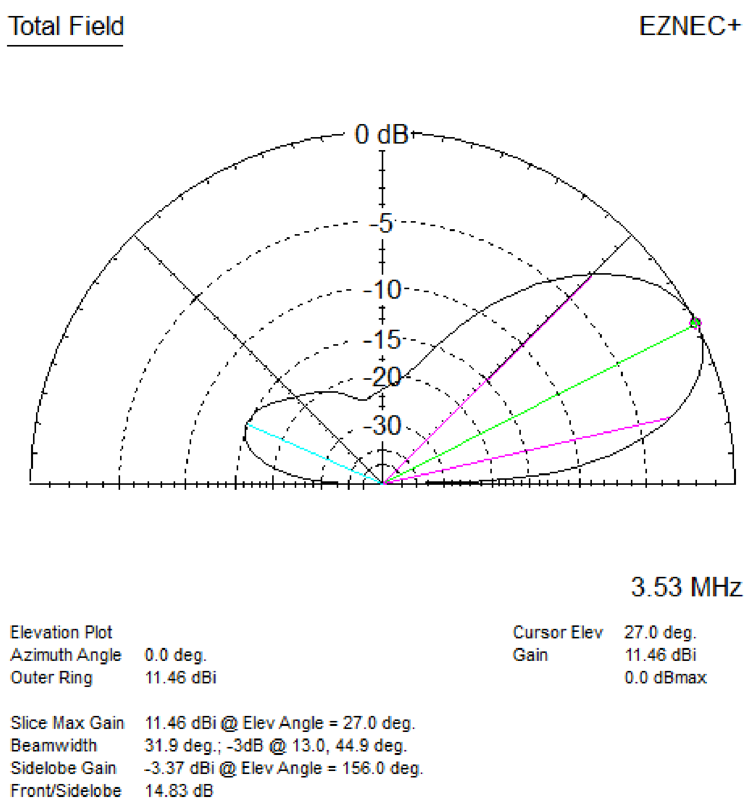
With correct dimensioning S/N is under control.

1. Transmitting antennas in receiving

On HF bands directivity of horizontally polarized directional antennas nearly equals to gain in dBi.

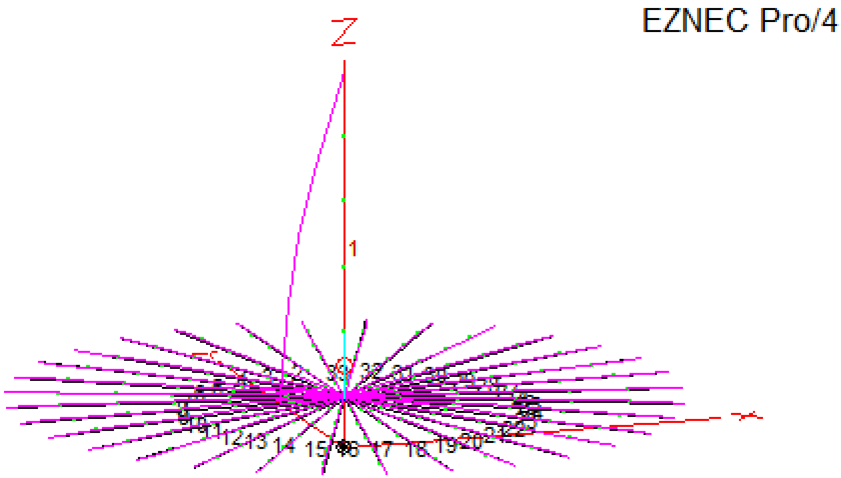
On lower bands transmitting antennas are often verticals , which means that ground losses are significant. In such a case directivity is not the same as antenna gain.

2-el full size Yagi up 41m, 3.53MHz



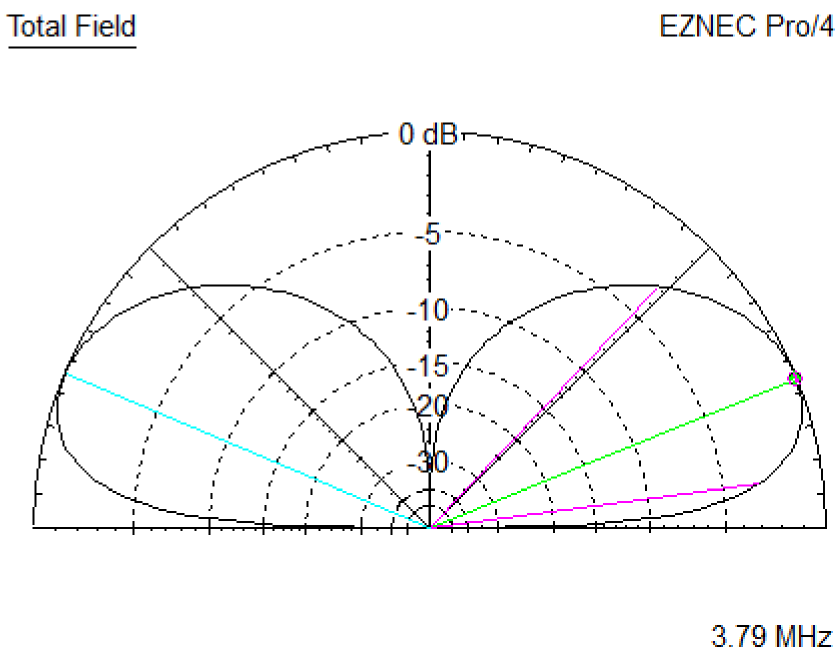
- Max gain = 11.46dBi @ 27deg
- Average gain= -0.86dBi
- > **Directivity = 12.32dB**
  - Beverage would be only 1.2dB better…
- These guys seldom use separate receiving antennas
- With 30m long elements directivity is the same 12.3dB.

¼ wave vertical for transmitting and receiving 3.8MHz



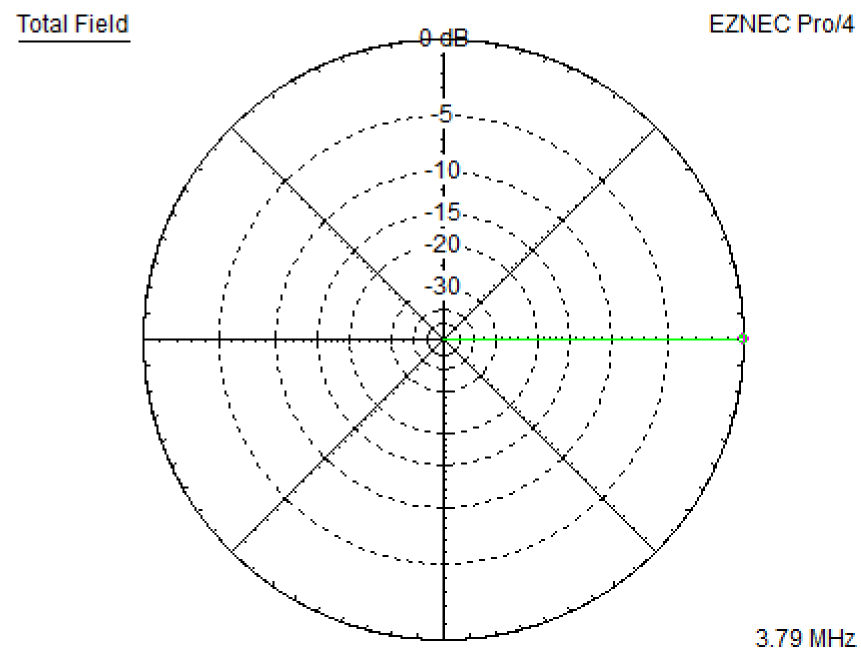
- Radiator 19.5m
- 32 radials, 3m above the ground
- Normal soil (0.005, 13)

¼ wave vertical for transmitting and receiving 3.8MHz



Elevation Plot		Cursor Elev	22.0 deg.
Azimuth Angle	0.0 deg.	Gain	0.31 dBi
Outer Ring	0.31 dBi		0.0 dBmax

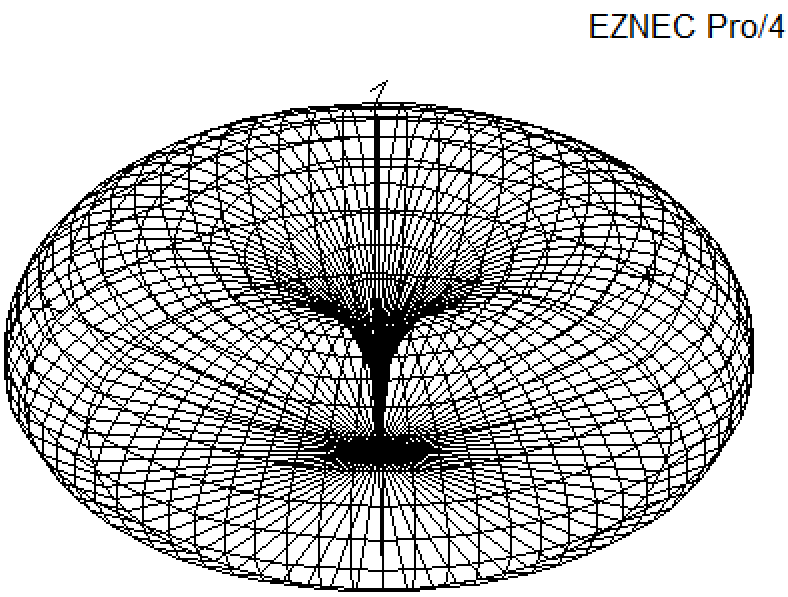
Slice Max Gain	0.31 dBi @ Elev Angle = 22.0 deg.
Beamwidth	38.8 deg.; -3dB @ 7.7, 46.5 deg.
Sidelobe Gain	0.31 dBi @ Elev Angle = 157.0 deg.
Front/Sidelobe	0.0 dB



Azimuth Plot		Cursor Az	0.0 deg.
Elevation Angle	22.0 deg.	Gain	0.31 dBi
Outer Ring	0.31 dBi		0.0 dBmax

Slice Max Gain	0.31 dBi @ Az Angle = 0.0 deg.
Front/Side	0.0 dB
Beamwidth	?
Sidelobe Gain	< -100 dBi
Front/Sidelobe	> 100 dB

¼ wave vertical for transmitting and receiving 3.8MHz



- Average gain= -5.07dBi
- Max gain= 0.31dBi @ 22 deg
- **Directivity= 5.38dB**
  - Receives from all azimuth directions equally well
  - Directivity in elevation
- Our receiving antennas shall be better than this

Low band receiving antennas Some examples

In all examples the wire is non-insulated.

The ground in all examples in so called normal ground, where conductivity is 5mS and dielectric factor is 13.

2. Beverage

Beverage is a traveling wave antenna, which is a straight wire, a transmission line. The ground serves as a return path. The line is terminated with a resistor. Value of the resistor equals to impedance of the line.

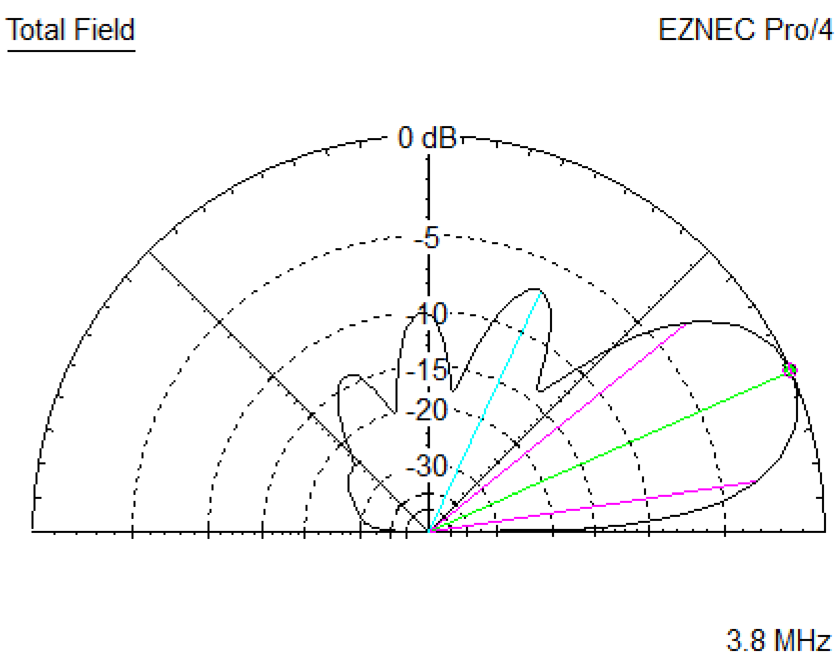
When vertically polarized signal arriving from low elevation meets the ground, the vector is leaning forward. This happens because >1 dielectric factor on ground level will slow down speed of the lower end of vector. Vertical polarization is converted this way to horizontal and the horizontal wire can catch it.

Those signals arriving from direction where the termination is and from low elevation angles, are summing up in the same phase at the antenna feed point, independently what part of the wire they arrived.

Beverage, 3.8MHz, 2λ

- Effective length here is 2 wave lengths
- 200m long 2mm wire, 1m high
- 600ohm termination is 20m from wire end
- Feedpoint is 20m from the other end
- 600/50ohm matching with a transformer
- Current distribution on 3.8MHz is shown on the left
- Grounding is here made with ¼ wave radials.
- Beverage receives vertical polarization. It works best on sandy soil but not so well on ocean.

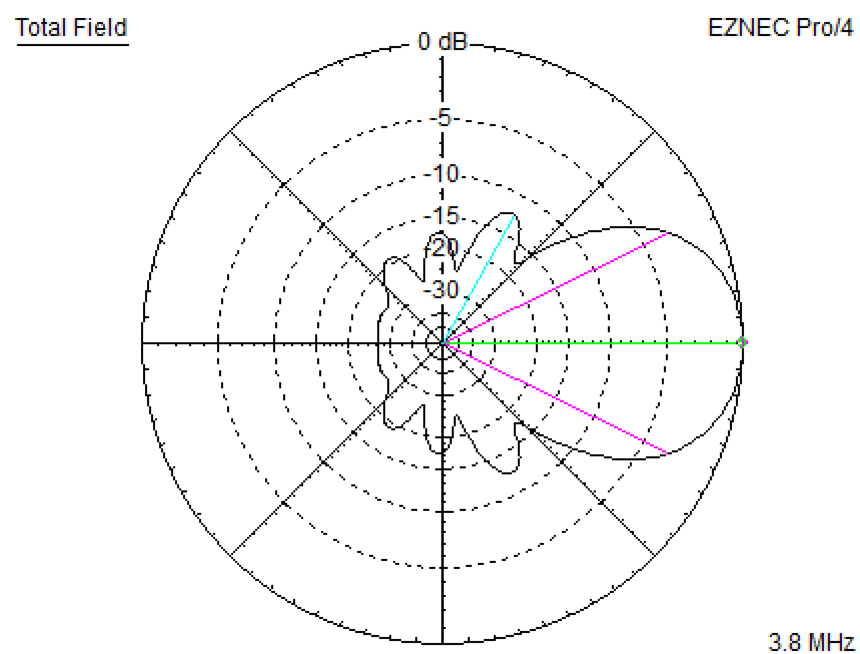
Beverage, 3.8MHz, 2λ



Elevation Plot
Azimuth Angle 0.0 deg.
Outer Ring -4.24 dBi

Cursor Elev 24.0 deg.
Gain -4.24 dBi
0.0 dBmax

Slice Max Gain -4.24 dBi @ Elev Angle = 24.0 deg.
Beamwidth 30.1 deg.; -3dB @ 8.8, 38.9 deg.
Sidelobe Gain -11.14 dBi @ Elev Angle = 65.0 deg.
Front/Sidelobe 6.9 dB

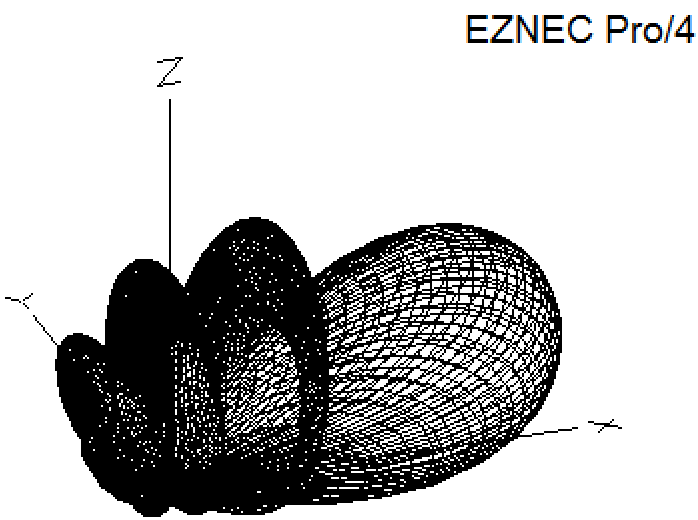


Azimuth Plot
Elevation Angle 24.0 deg.
Outer Ring -4.24 dBi

Cursor Az 0.0 deg.
Gain -4.24 dBi
0.0 dBmax

Slice Max Gain -4.24 dBi @ Az Angle = 0.0 deg.
Front/Back 26.6 dB
Beamwidth 51.6 deg.; -3dB @ 334.2, 25.8 deg.
Sidelobe Gain -16.51 dBi @ Az Angle = 61.0 deg.
Front/Sidelobe 12.27 dB

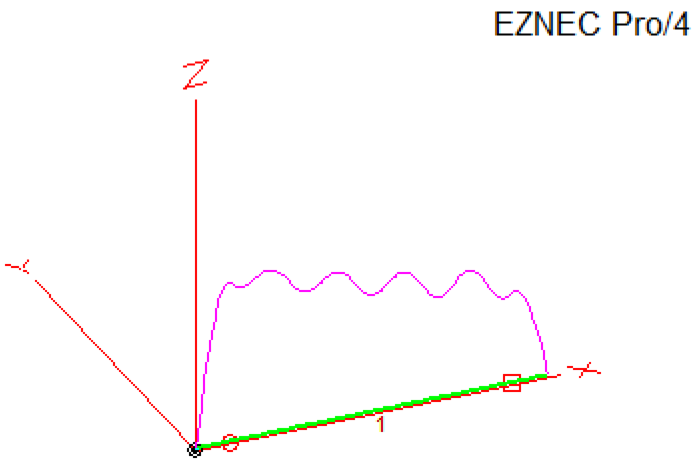
Beverage, 3.8MHz, 2λ



- Average gain= -17.8dB
  - Waste margin is 17dB with 10dB noise figure
  - > A pre-amp is preferred
- Gain= -4.24dB @ 24deg
- **Directivity** = -4.24- (-17.8)=**13.56dB**

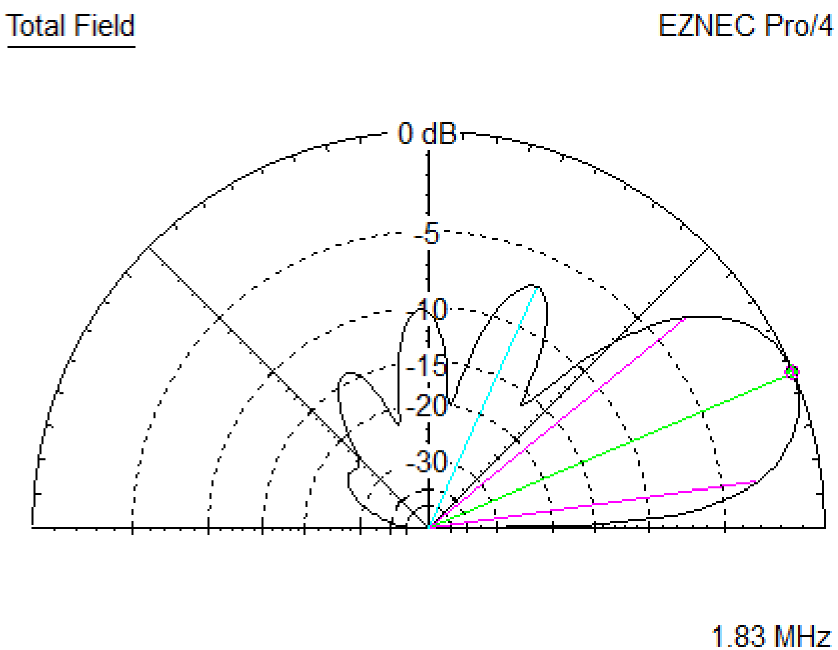
- This is a good reference for receiving antennas
- When compared to our ¼ wave TX vertical, this Beverage has 13.56-5.38= <u>8.18dB advantage in directivity</u>

Beverage, 1.83MHz, 2λ



- Effective length is 2 wave lengths
- 415m long 2mm wire, 2m high
- 600ohm termination 40m from wire end
- Feedpoint 40m from the other end
- 600/50ohm matching with a transformer
- Current distribution on 1.83MHz is shown on the left
- Grounding is here made with ¼ wave radials.
- Beverage receives vertical polarization. It works best on sandy soil but not so well on ocean.

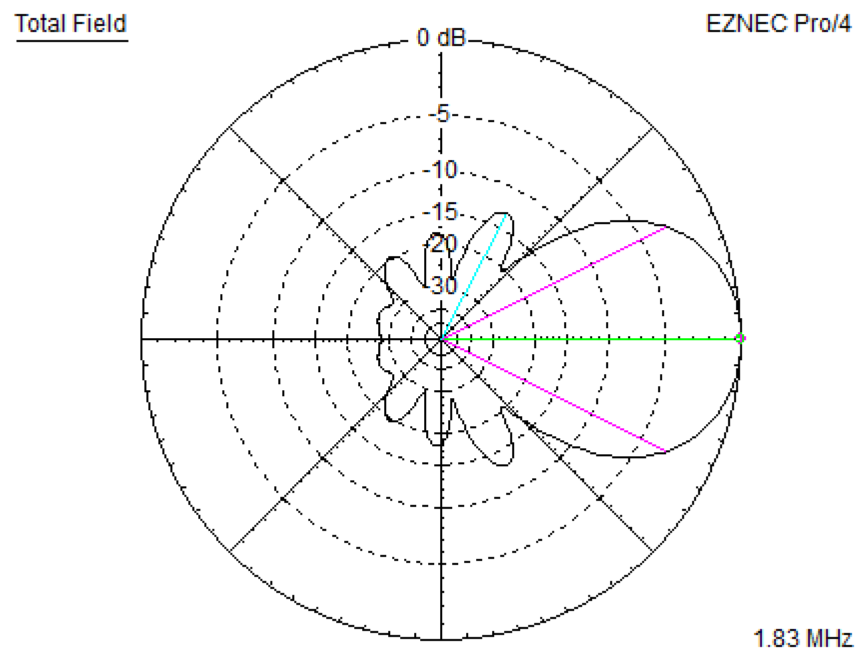
Beverage, 1.83MHz, 2λ



Elevation Plot
Azimuth Angle 0.0 deg.
Outer Ring -5.35 dBi

Cursor Elev 23.0 deg.
Gain -5.35 dBi
0.0 dBmax

Slice Max Gain -5.35 dBi @ Elev Angle = 23.0 deg.
Beamwidth 31.2 deg.; -3dB @ 7.9, 39.1 deg.
Sidelobe Gain -12.33 dBi @ Elev Angle = 66.0 deg.
Front/Sidelobe 6.98 dB

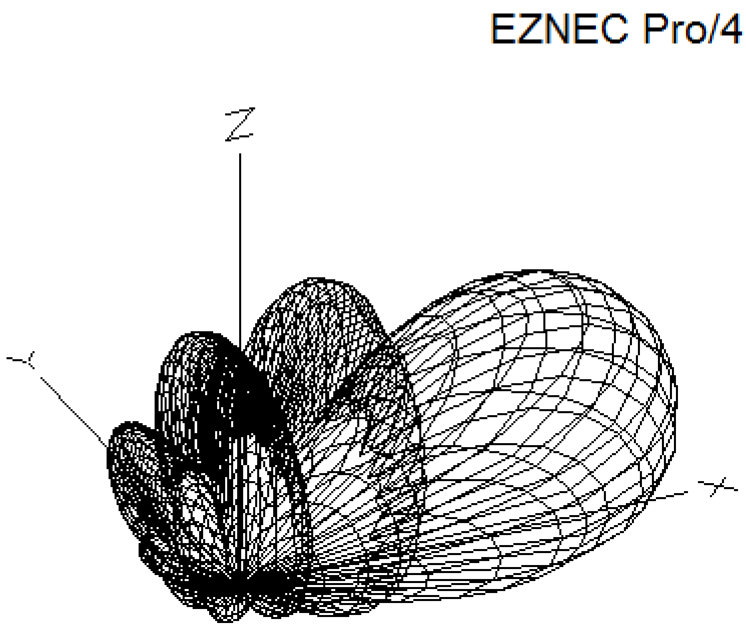


Azimuth Plot
Elevation Angle 23.0 deg.
Outer Ring -5.35 dBi

Cursor Az 0.0 deg.
Gain -5.35 dBi
0.0 dBmax

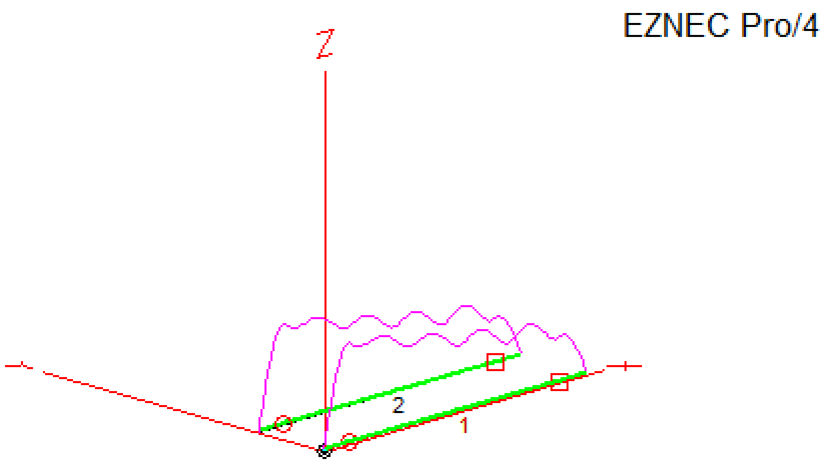
Slice Max Gain -5.35 dBi @ Az Angle = 0.0 deg.
Front/Back 27.4 dB
Beamwidth 52.8 deg.; -3dB @ 333.6, 26.4 deg.
Sidelobe Gain -18.22 dBi @ Az Angle = 62.0 deg.
Front/Sidelobe 12.87 dB

Beverage, 1.83MHz, 2λ



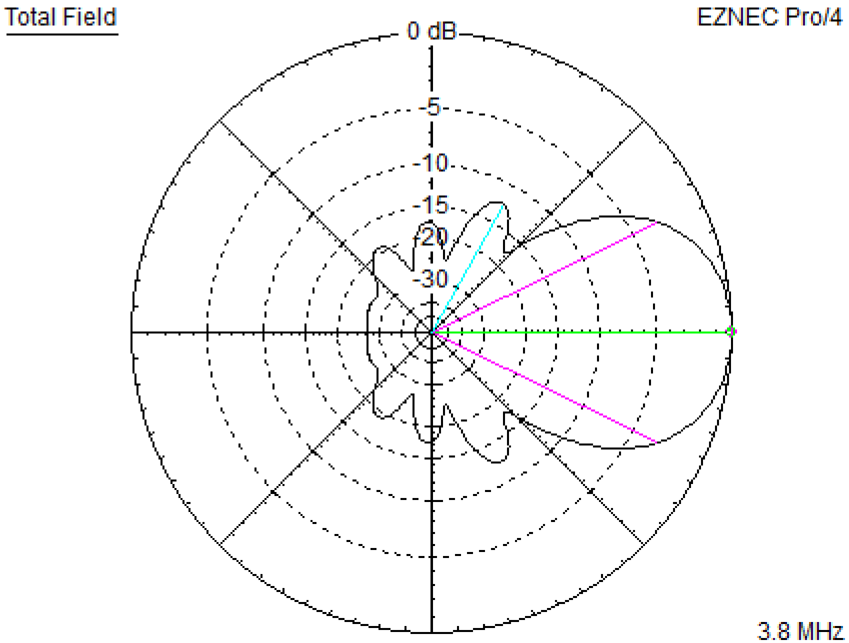
- Average gain= -18.89dB
  - Waste margin is 26dB with 10dB noise figure
  - > No need for pre-amp
- Max gain= -5.35dB @ 23deg
- **Directivity** = -5.35- (-18.89)=**13.54dB**

Two parallel Beverages, 3.8MHz, 2λ



- Wires as described before
- Distance between wires 20, 40, 50 or 60m
- The results are shown on the next pages, including the single wire case

Single Beverage, 3.8MHz, 2λ



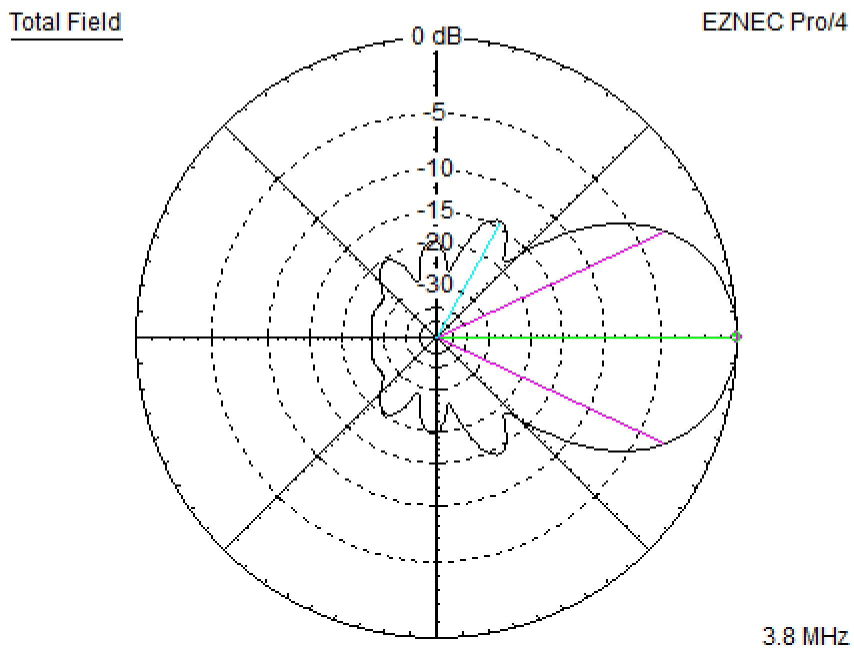
Azimuth Plot		Cursor Az	0.0 deg.
Elevation Angle	24.0 deg.	Gain	-4.24 dBi
Outer Ring	-4.24 dBi		0.0 dBmax

Slice Max Gain	-4.24 dBi @ Az Angle = 0.0 deg.
Front/Back	26.6 dB
Beamwidth	51.6 deg.; -3dB @ 334.2, 25.8 deg.
Sidelobe Gain	-16.51 dBi @ Az Angle = 61.0 deg.
Front/Sidelobe	12.27 dB

- Average gain= -17.8dB
- Max gain= -4.24dB @ 24deg

- **Directivity= 13.5dB**

Two Beverages parallel, distance 20m, 3.8MHz



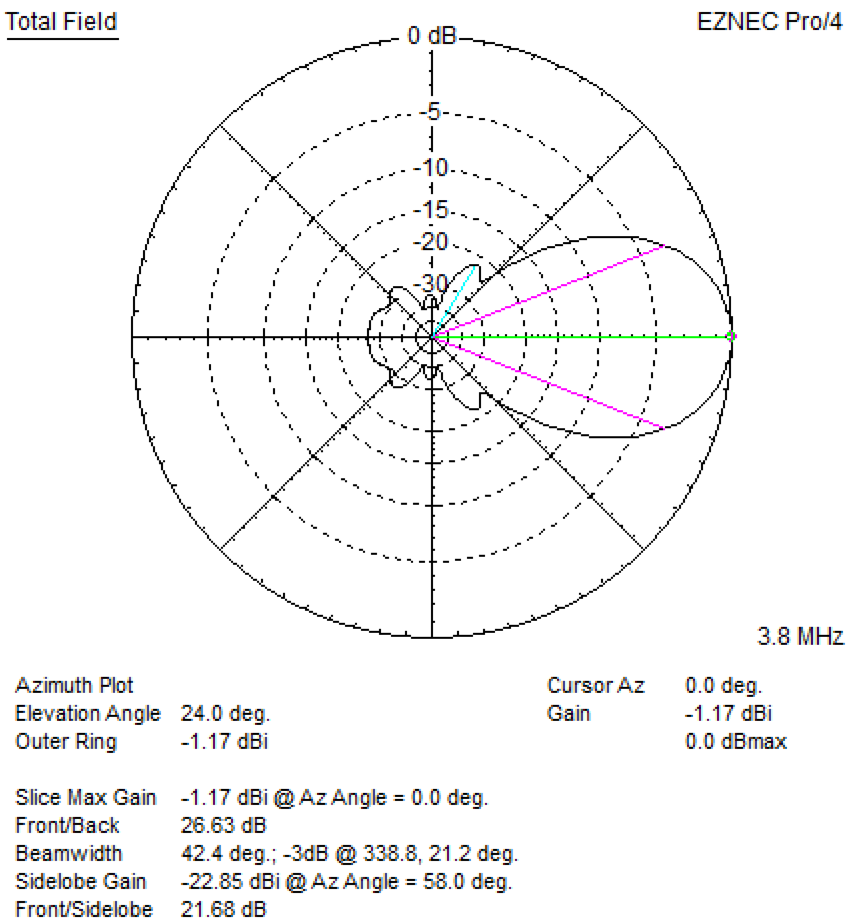
Azimuth Plot		Cursor Az	0.0 deg.
Elevation Angle	24.0 deg.	Gain	-1.3 dBi
Outer Ring	-1.3 dBi		0.0 dBmax

Slice Max Gain	-1.3 dBi @ Az Angle = 0.0 deg.
Front/Back	26.33 dB
Beamwidth	49.8 deg.; -3dB @ 335.1, 24.9 deg.
Sidelobe Gain	-15.36 dBi @ Az Angle = 61.0 deg.
Front/Sidelobe	14.06 dB

- Average gain= -15.08dB
- Max gain= -1.3dB@ 24deg

- **Directivity= 13.8dB**

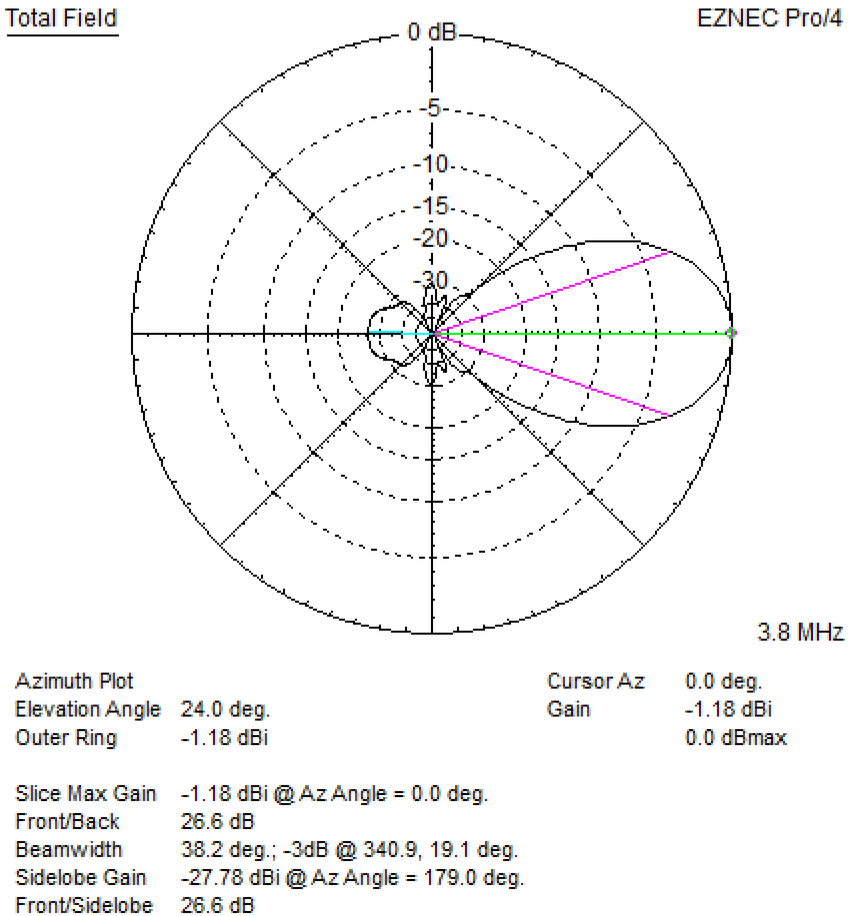
Two Beverages parallel, distance 40m, 3.8MHz



- Average gain= -15.83dB
- Max gain= -1.17dB@ 24deg

- **Directivity= 14.66dB**

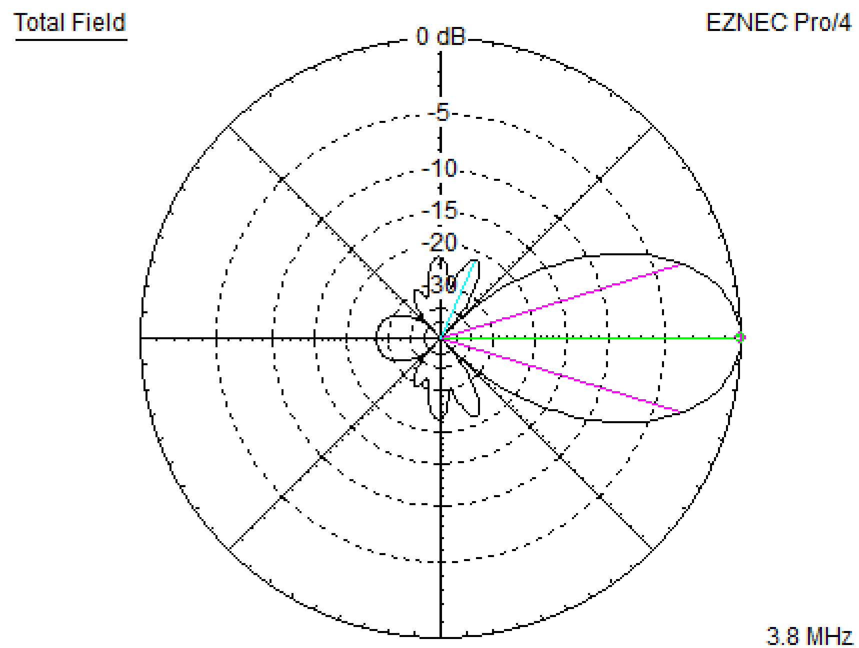
Two Beverages parallel, distance 50m, 3.8MHz



- Average gain= -16.33dB
- Max gain= -1.18dB@ 24deg

- **Directivity= 15.15dB**

Two Beverages parallel, distance 60m, 3.8MHz



Azimuth Plot		Cursor Az	0.0 deg.
Elevation Angle	24.0 deg.	Gain	-1.2 dBi
Outer Ring	-1.2 dBi		0.0 dBmax

Slice Max Gain	-1.2 dBi @ Az Angle = 0.0 deg.
Front/Back	26.57 dB
Beamwidth	34.4 deg.; -3dB @ 342.8, 17.2 deg.
Sidelobe Gain	-22.66 dBi @ Az Angle = 66.0 deg.
Front/Sidelobe	21.46 dB

- Average gain= -16.81dB
- Max gain= -1.2dB@ 24deg
- **Directivity= 15.61dB**
- When compared to our ¼ wave TX vertical, this Beverage has 15.61 - 5.38 = 10.23dB advantage in directivity

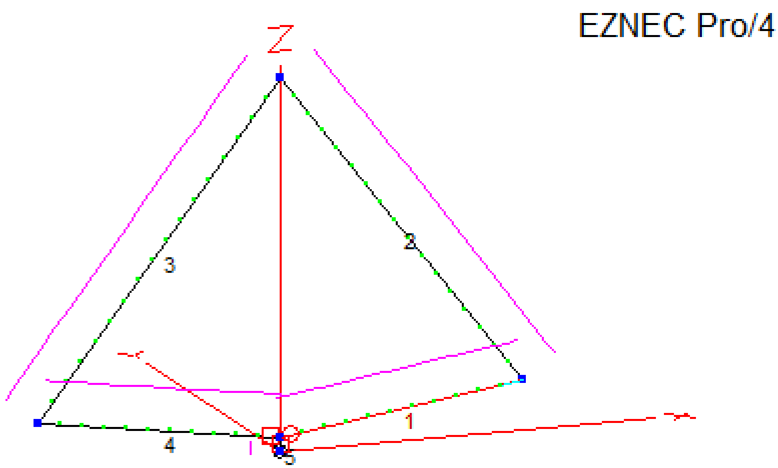
3. Loop-like travelling wave antennas

K9AY, Flag, EWE, DHDL

Loop-like travelling wave antennas

- In travelling wave antennas current amplitude is constant along the wire, but the phase is changing as function of distance from the feedpoint.
- By bending a wire into form of a loop and terminating it with a matching resistor we can <u>imitate two element phased vertical array</u>.
- As we cannot avoid horizontal sections in the loop, these antennas receive also horizontal polarization. This broadens the vertical radiation pattern upwards, which is not a good thing.
- K9AY, Flag and EWE have almost equal performance
- In DHDL the 40deg sloping wires form like a 3rd element and improve directivity. But at the same time average gain drops to such a low level that it is impossible to fully compensate with any pre-amp.

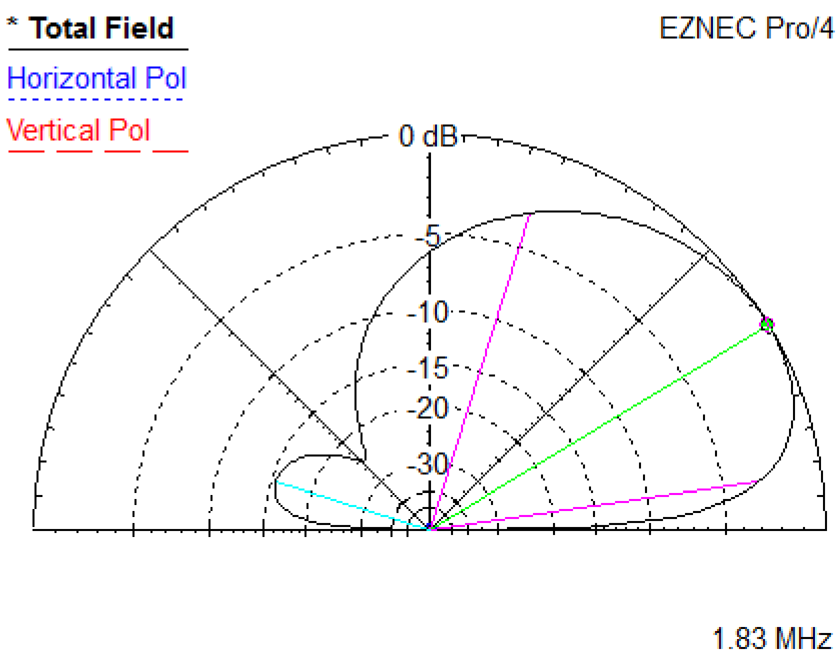
K9AY loop, 1.83MHz



- Wires 2 ja 3 are 8.2m
- Wires 1 ja 4 are 5.05m
- In wire 4 resistor is 400 ohm
- Wire 5 is to ground, resistance 55ohm
- Feedpoint on wire 1, 500ohm
- Wire dia 2mm
- Normal ground
- Receives mainly vertical polarization
- Above 45 deg elevation horizontal polarization gets significant

K9AY loop, 1.83MHz

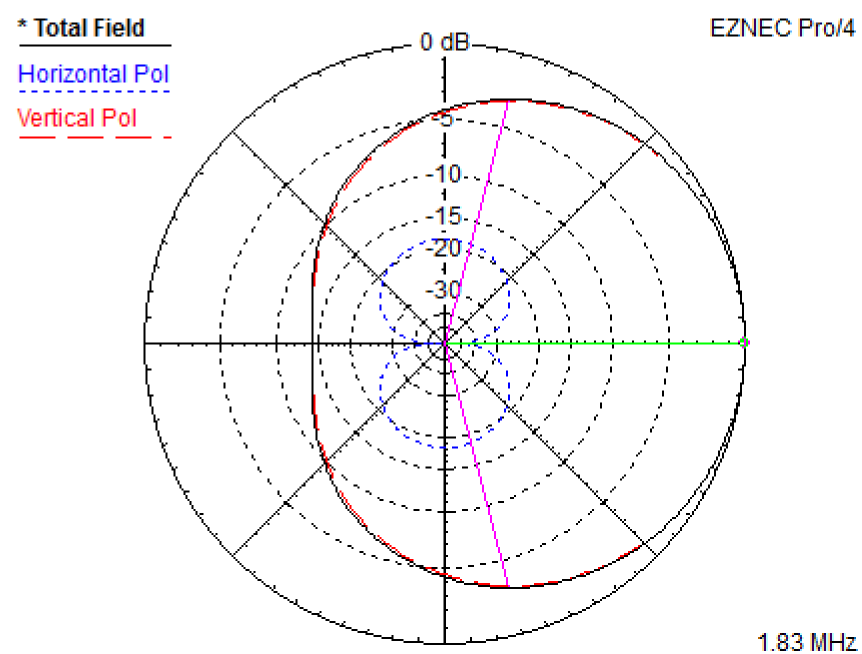
TOA=10 deg



Elevation Plot
Azimuth Angle 0.0 deg.
Outer Ring -25.56 dBi

Cursor Elev 31.0 deg.
Gain -25.56 dBi
0.0 dBmax

Slice Max Gain -25.56 dBi @ Elev Angle = 31.0 deg.
Beamwidth 64.2 deg.; -3dB @ 8.2, 72.4 deg.
Sidelobe Gain -40.97 dBi @ Elev Angle = 163.0 deg.
Front/Sidelobe 15.41 dB



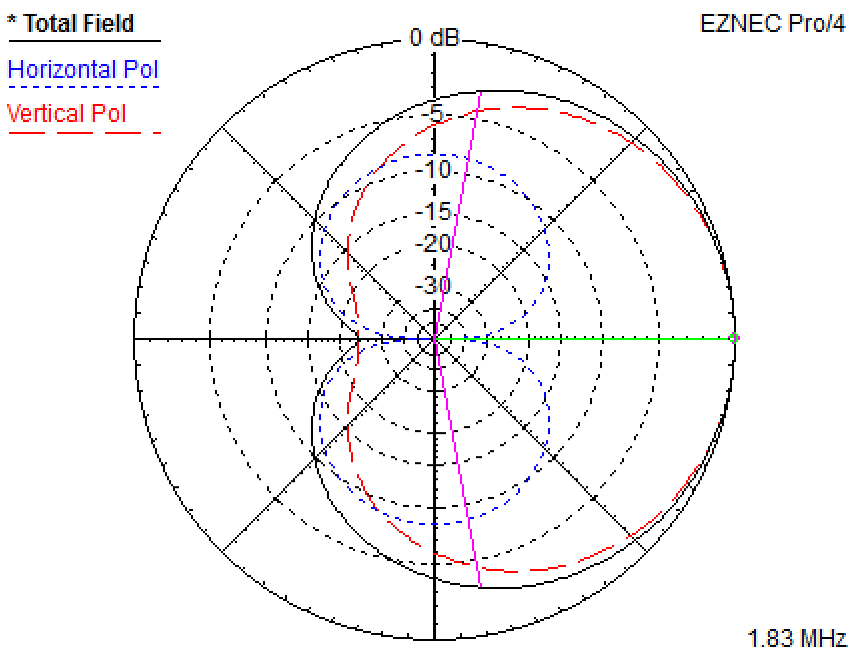
Azimuth Plot
Elevation Angle 10.0 deg.
Outer Ring -27.78 dBi

Cursor Az 0.0 deg.
Gain -27.78 dBi
0.0 dBmax

Slice Max Gain -27.78 dBi @ Az Angle = 0.0 deg.
Front/Back 14.08 dB
Beamwidth 151.0 deg.; -3dB @ 284.5, 75.5 deg.
Sidelobe Gain < -100 dBi
Front/Sidelobe > 100 dB

K9AY loop, 1.83MHz, high arrival angles, horizontal patterns

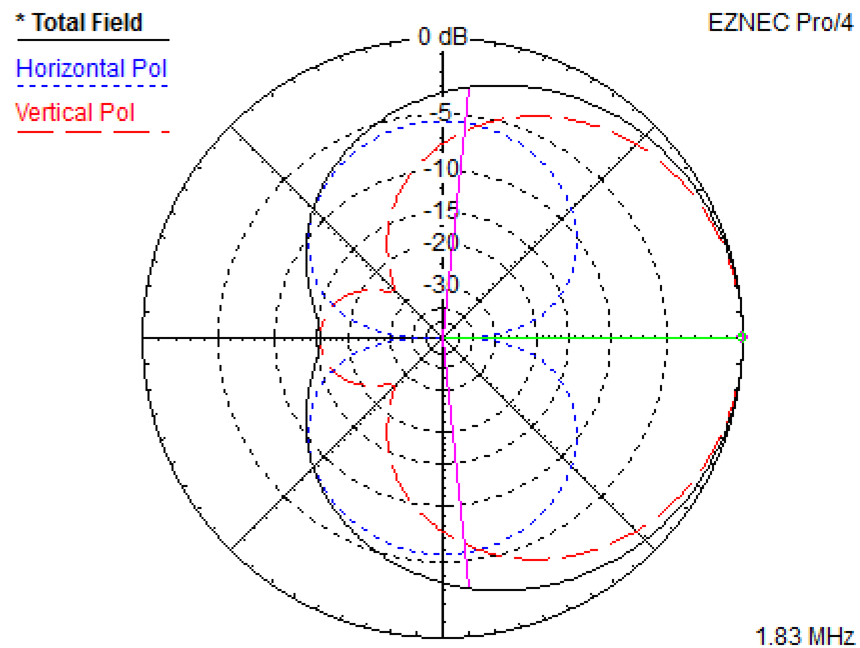
TOA=45 deg



Azimuth Plot		Cursor Az	0.0 deg.
Elevation Angle	45.0 deg.	Gain	-25.96 dBi
Outer Ring	-25.96 dBi		0.0 dBmax

Slice Max Gain -25.96 dBi @ Az Angle = 0.0 deg.
Front/Back 23.63 dB
Beamwidth 158.8 deg.; -3dB @ 280.6, 79.4 deg.
Sidelobe Gain < -100 dBi
Front/Sidelobe > 100 dB

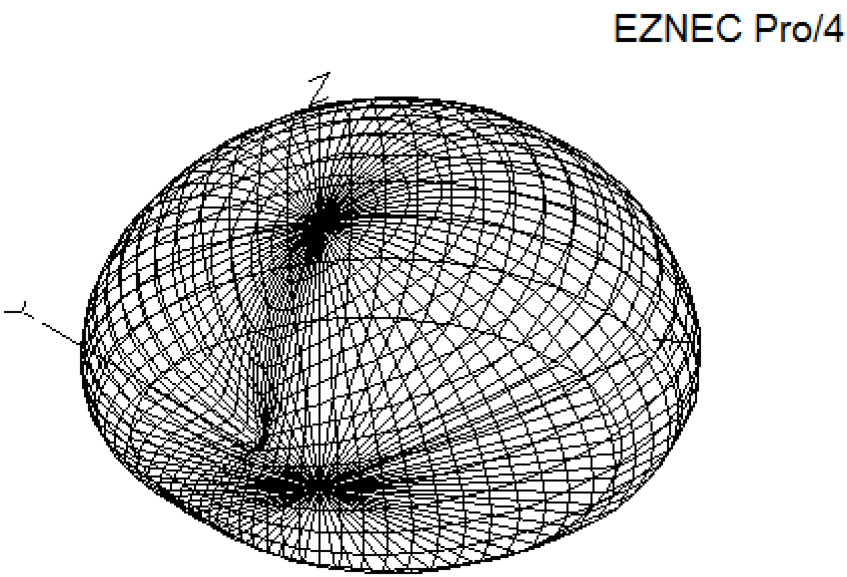
TOA=60 deg



Azimuth Plot		Cursor Az	0.0 deg.
Elevation Angle	60.0 deg.	Gain	-27.1 dBi
Outer Ring	-27.1 dBi		0.0 dBmax

Slice Max Gain -27.1 dBi @ Az Angle = 0.0 deg.
Front/Back 15.36 dB
Beamwidth 168.4 deg.; -3dB @ 275.8, 84.2 deg.
Sidelobe Gain < -100 dBi
Front/Sidelobe > 100 dB

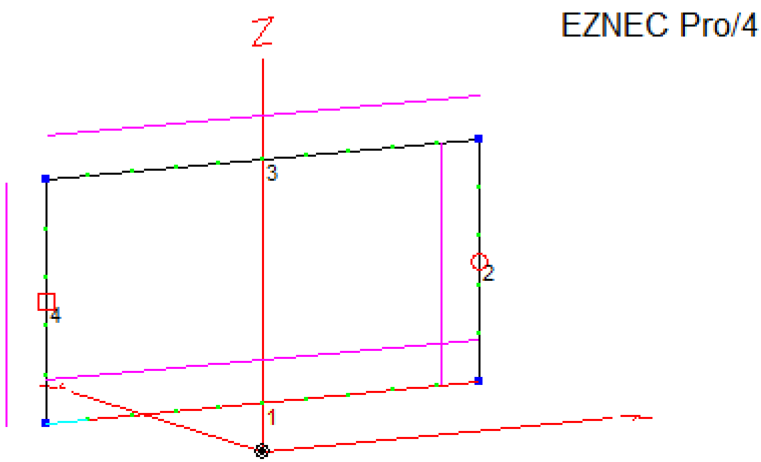
K9AY loop, 1.83MHz



- Average gain=-33.25dBi
  - Waste margin is 33dB with 3dB noise figure
  - A pre-amp is needed
- Max Gain=-25.56dBi @ 31deg
- **Directivity=7.7dB**

- When compared to our ¼ wave TX vertical, this K9AY loop has 7.70-5.38= <u>2.32dB advantage in directivity</u>
  - Modest

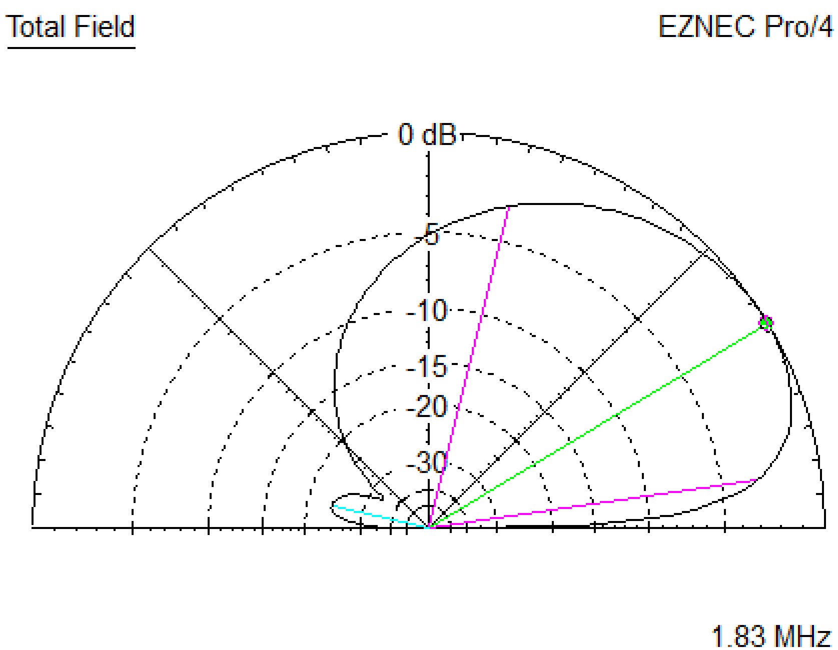
Flag, 1.83MHz

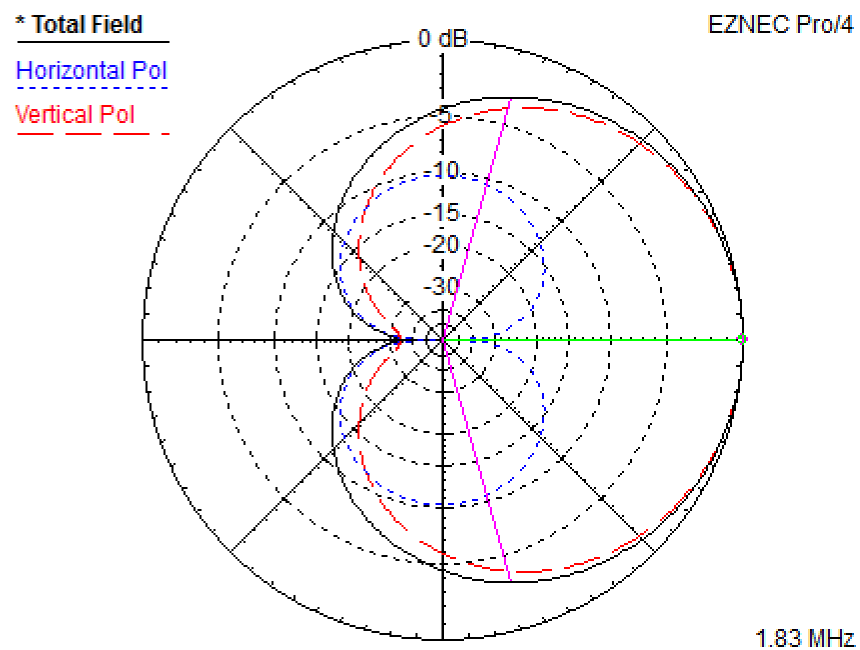


- Wires 1 and 3 are 10m long
- Wires 2 and 4 are 5m
- Termination resistor in wire 4 is 900ohm
- Feedpoint on wire 2, 1000ohm

- w2 and w4 act like phased verticals.
- Wire 4 is fed by open transmission line w1w3, which also generate the needed phase shift
- Unfortunately those horizontal wires also receive horizontal polarized signals from high angles.

Flag, 1.83MHz





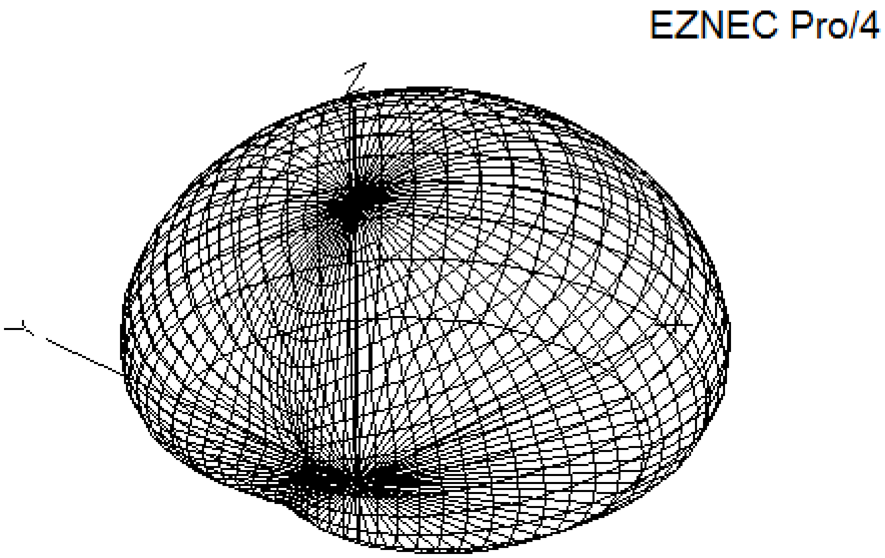
Elevation Plot		Cursor Elev	31.0 deg.
Azimuth Angle	0.0 deg.	Gain	-27.54 dBi
Outer Ring	-27.54 dBi		0.0 dBmax

Slice Max Gain	-27.54 dBi @ Elev Angle = 31.0 deg.
Beamwidth	67.5 deg.; -3dB @ 8.4, 75.9 deg.
Sidelobe Gain	-51.24 dBi @ Elev Angle = 167.0 deg.
Front/Sidelobe	23.7 dB

Azimuth Plot		Cursor Az	0.0 deg.
Elevation Angle	31.0 deg.	Gain	-27.54 dBi
Outer Ring	-27.54 dBi		0.0 dBmax

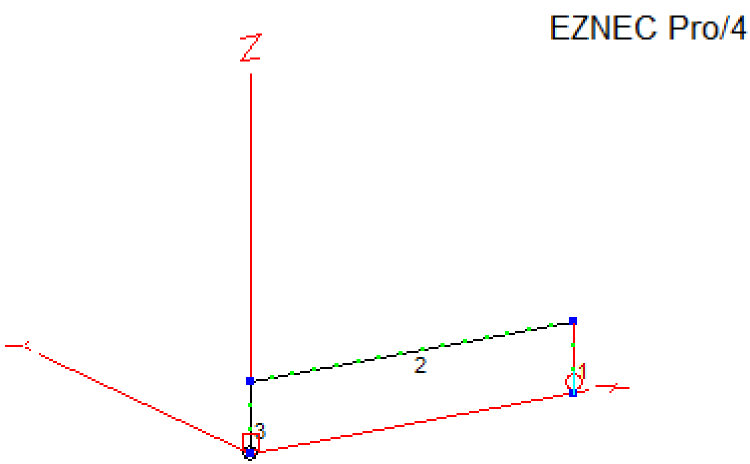
Slice Max Gain	-27.54 dBi @ Az Angle = 0.0 deg.
Front/Back	33.52 dB
Beamwidth	149.0 deg.; -3dB @ 285.5, 74.5 deg.
Sidelobe Gain	< -100 dBi
Front/Sidelobe	> 100 dB

Flag, 1.83MHz



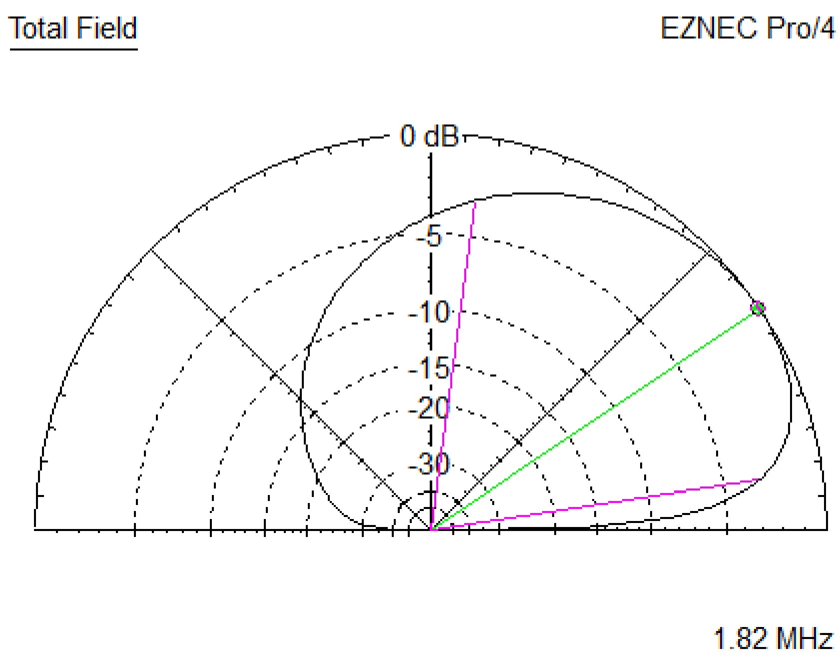
- Average gain -35.3dBi
  - Waste margin is 33dB @ F=3dB
  - A pre-amp with 3dB noise figure is not good enough. We would need 0.7dB noise figure!
- Max Gain=-27.54dBi @ 31deg
- **Directivity= 7.76dB**
  - Modest

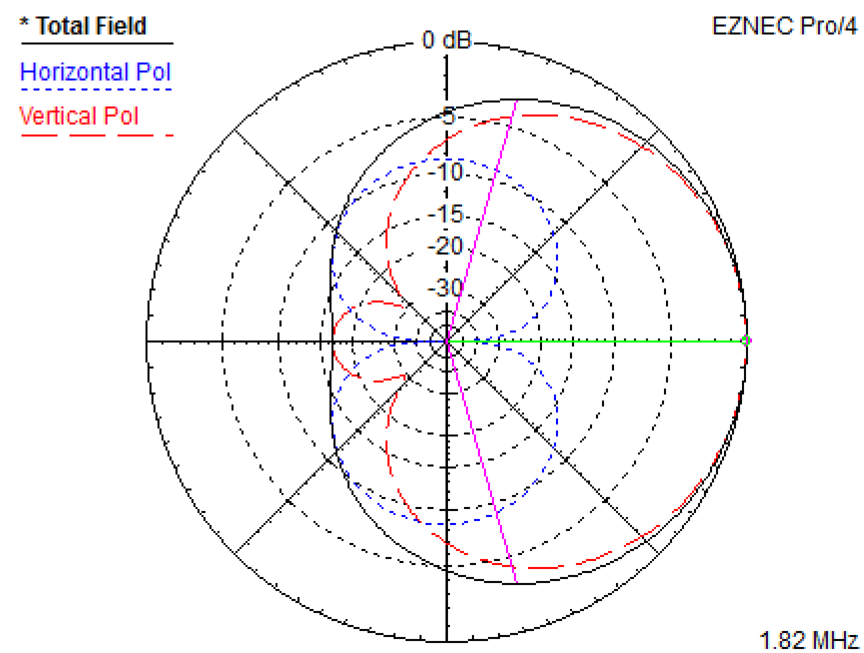
EWE (u) receiving loop, 1.82MHz



- Wire 2 is 15m long, 3m high
- Resistor in wire 3 is 1000 ohm
- Feedpoint on w1 is 450 ohm

EWE receiving loop, 1.82MHz





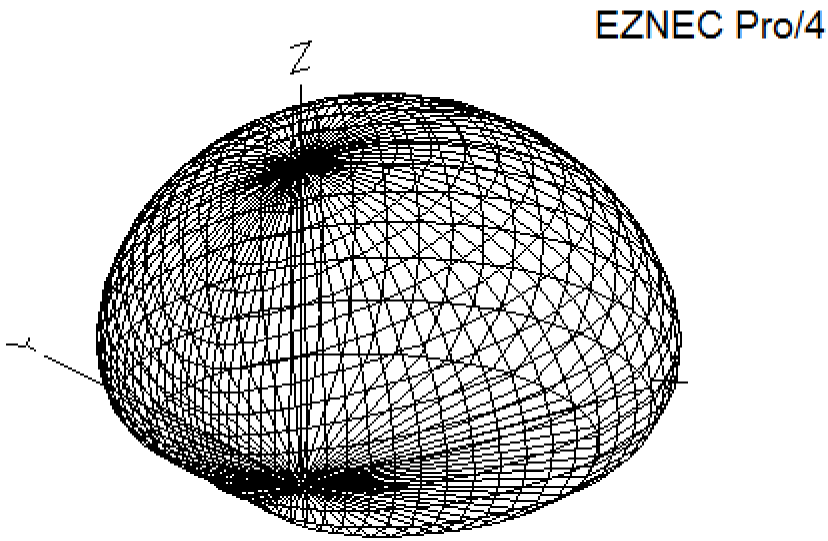
Elevation Plot		Cursor Elev	34.0 deg.
Azimuth Angle	0.0 deg.	Gain	-22.63 dBi
Outer Ring	-22.63 dBi		0.0 dBmax

Slice Max Gain	-22.63 dBi @ Elev Angle = 34.0 deg.
Beamwidth	73.9 deg.; -3dB @ 8.6, 82.5 deg.
Sidelobe Gain	< -100 dBi
Front/Sidelobe	> 100 dB

Azimuth Plot		Cursor Az	0.0 deg.
Elevation Angle	34.0 deg.	Gain	-22.63 dBi
Outer Ring	-22.63 dBi		0.0 dBmax

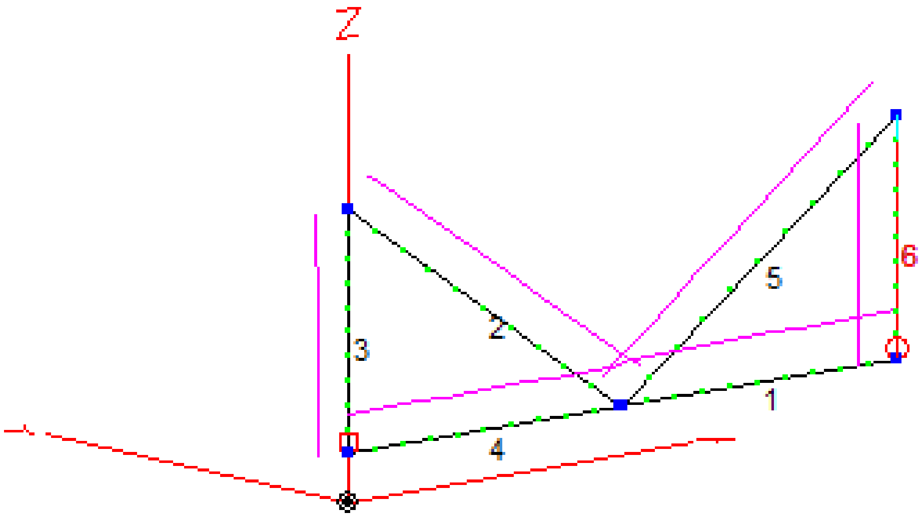
Slice Max Gain	-22.63 dBi @ Az Angle = 0.0 deg.
Front/Back	16.64 dB
Beamwidth	147.6 deg.; -3dB @ 286.2, 73.8 deg.
Sidelobe Gain	< -100 dBi
Front/Sidelobe	> 100 dB

EWE receiving loop, 1.82MHz



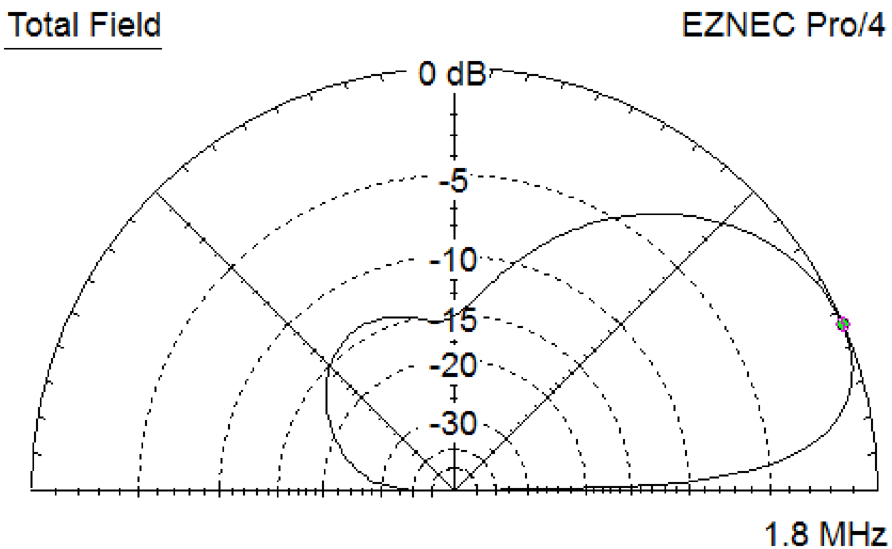
- Average gain = -30.26dBi
  - Waste margin is 33dB @ F=3dB
  - Needs pre-amp, noise figure at least 5dB
- Max Gain= -22.63dBi @ 34deg
- **Directivity = 7.6dB**
  - modest

Double Half Delta Loop (DHDL)



- Lower wires 1 and 4 are 1.5m above the ground, dia 1mm
- w3-w6 distance is 22m
- w3 and w6 length 7.5m
- Termination resistance in w3 is 1200ohm
- Feedpoint impedance on w6 is 800ohm

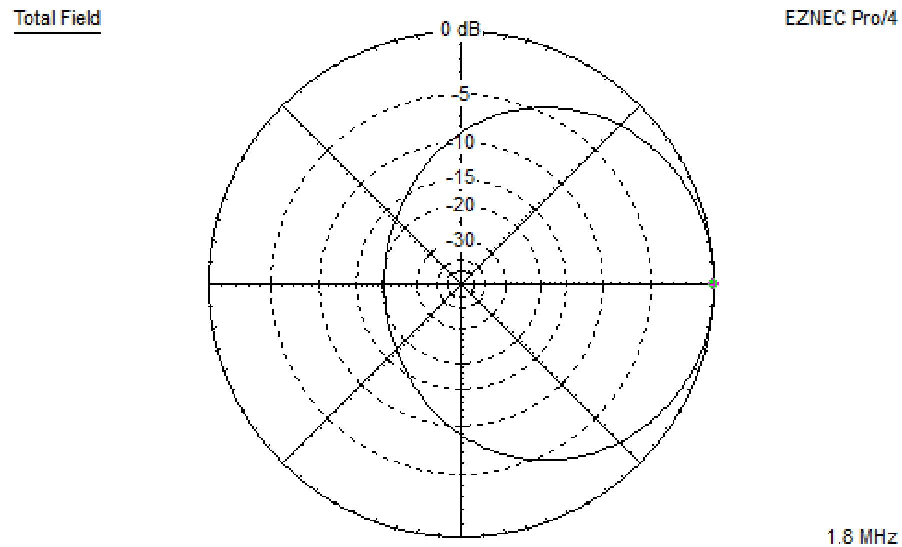
DHDL on 160m, normal ground



Elevation Plot
Azimuth Angle 0.0 deg.
Outer Ring -28.48 dBi

Cursor Elev 23.0 deg.
Gain -28.48 dBi
0.0 dBmax

Slice Max Gain -28.48 dBi @ Elev Angle = 23.0 deg.
Beamwidth 44.0 deg.; -3dB @ 7.0, 51.0 deg.
Sidelobe Gain -42.33 dBi @ Elev Angle = 119.0 deg.
Front/Sidelobe 13.85 dB



Azimuth Plot
Elevation Angle 23.0 deg.
Outer Ring -28.48 dBi

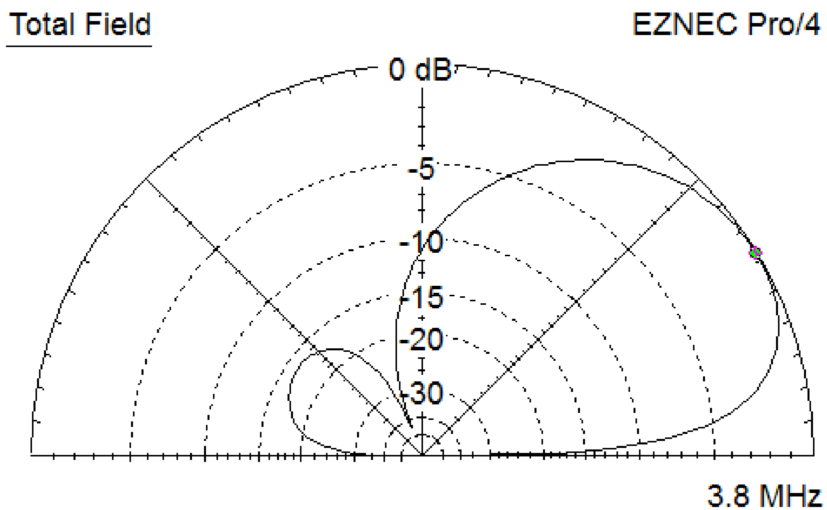
Cursor Az 0.0 deg.
Gain -28.48 dBi
0.0 dBmax

Slice Max Gain -28.48 dBi @ Az Angle = 0.0 deg.
Front/Back 20.44 dB
Beamwidth 106.6 deg.; -3dB @ 306.8, 53.4 deg.
Sidelobe Gain < -100 dBi
Front/Sidelobe > 100 dB

DHDL on 160m, normal ground

- Average gain = -38.32dBi
  - Waste margin is 33dB @ F=3dB
  - Impossible to compensate the difference with any pre-amp
- Max gain -28.48dBi @ **23deg,** good angle, better than K9AY
- **Directivity** = -28.48 - - 38.32 = 9.84dB
  - 2.1dB better than K9AY, Flag or EWE

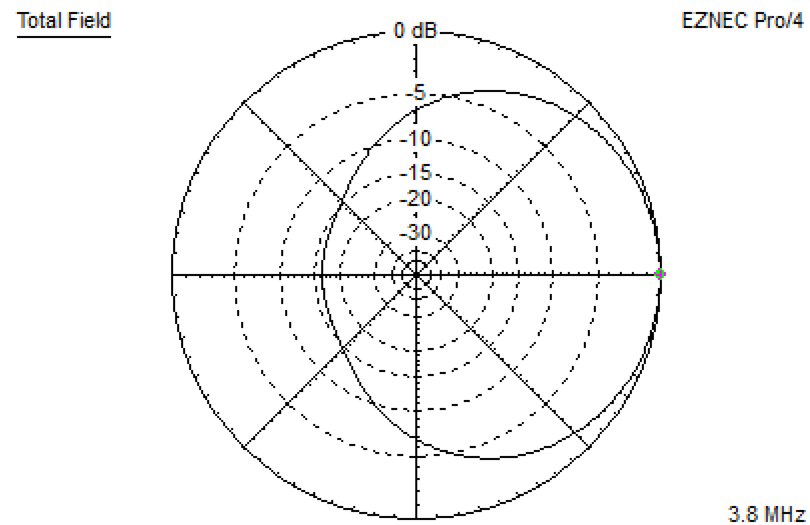
The same DHDL on 80m



Elevation Plot
Azimuth Angle 0.0 deg.
Outer Ring -11.63 dBi

Cursor Elev 31.0 deg.
Gain -11.63 dBi
0.0 dBmax

Slice Max Gain -11.63 dBi @ Elev Angle = 31.0 deg.
Beamwidth 54.1 deg.; -3dB @ 9.6, 63.7 deg.
Sidelobe Gain -27.86 dBi @ Elev Angle = 144.0 deg.
Front/Sidelobe 16.23 dB



Azimuth Plot
Elevation Angle 31.0 deg.
Outer Ring -11.63 dBi

Cursor Az 0.0 deg.
Gain -11.63 dBi
0.0 dBmax

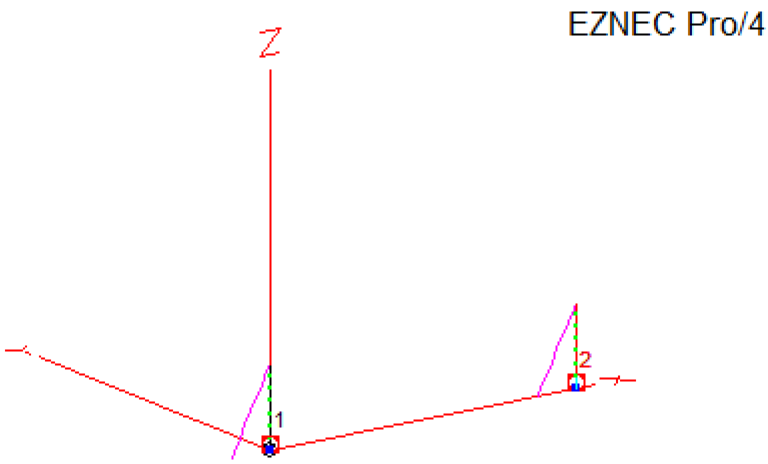
Slice Max Gain -11.63 dBi @ Az Angle = 0.0 deg.
Front/Back 16.34 dB
Beamwidth 126.0 deg.; -3dB @ 297.1, 63.1 deg.
Sidelobe Gain < -100 dBi
Front/Sidelobe > 100 dB

The same DHDL on 80m

- Average gain -20.59dBi
  - Waste margin with 10dB noise figure @ 80m is 17dB
  - Waste margin with 3dB noise figure @ 80m is 24dB
  - > <u>F=3dB pre-amp is good to have</u>
- Max gain -11.63dBi @ 31deg
- **Directivity** = -11.63 - - 20.59 = 8.96dB

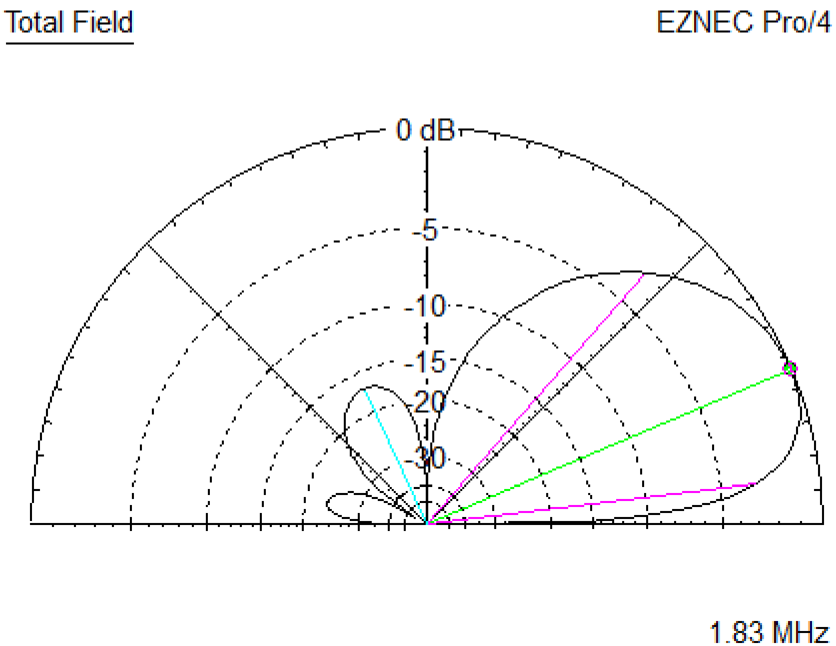
4. Phased vertical arrays

2 short verticals, phased, 1.83MHz



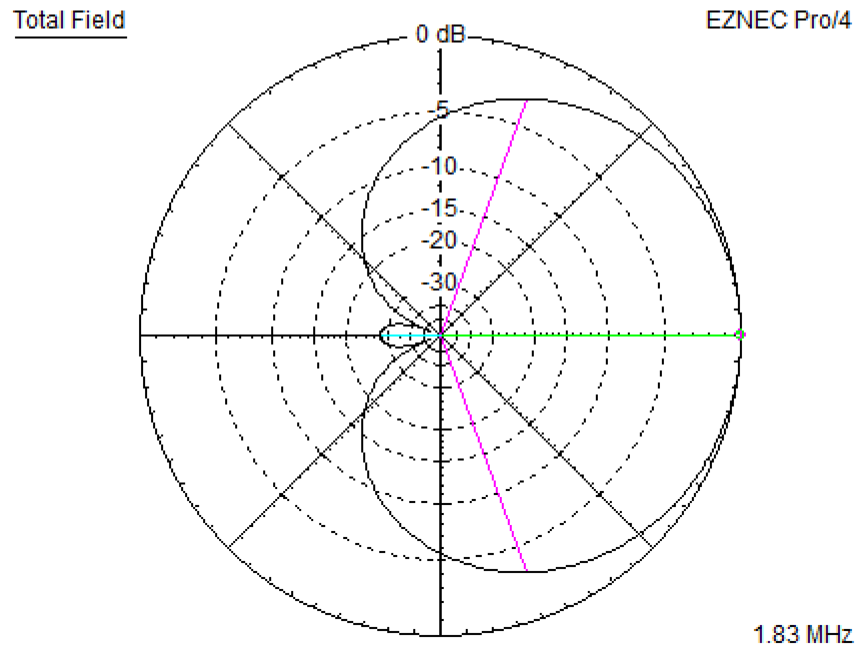
- Verticals 6m high, with high impedance pre-amps, ground rod, no radials
- Spacing 25m
- Current relation 1/1
- Phase relation 0/-133 deg

2 short verticals, phased, 1.83MHz



Elevation Plot		Cursor Elev	23.0 deg.
Azimuth Angle	0.0 deg.	Gain	-9.95 dBi
Outer Ring	-9.95 dBi		0.0 dBmax

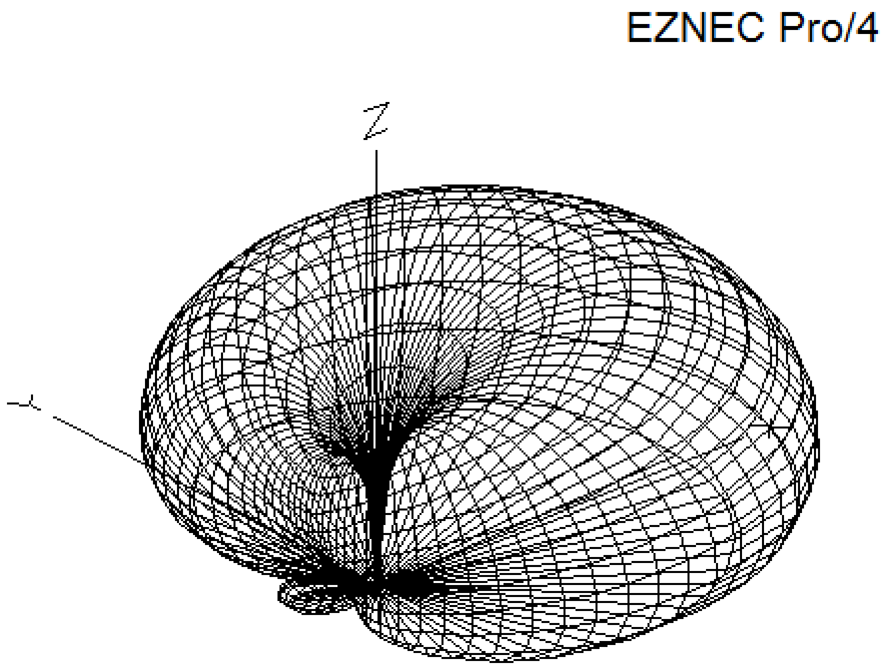
Slice Max Gain	-9.95 dBi @ Elev Angle = 23.0 deg.
Beamwidth	42.1 deg.; -3dB @ 6.9, 49.0 deg.
Sidelobe Gain	-26.72 dBi @ Elev Angle = 115.0 deg.
Front/Sidelobe	16.77 dB



Azimuth Plot		Cursor Az	0.0 deg.
Elevation Angle	23.0 deg.	Gain	-9.95 dBi
Outer Ring	-9.95 dBi		0.0 dBmax

Slice Max Gain	-9.95 dBi @ Az Angle = 0.0 deg.
Front/Back	27.63 dB
Beamwidth	140.0 deg.; -3dB @ 290.0, 70.0 deg.
Sidelobe Gain	-37.58 dBi @ Az Angle = 180.0 deg.
Front/Sidelobe	27.63 dB

2 short verticals, phased, 1.83MHz

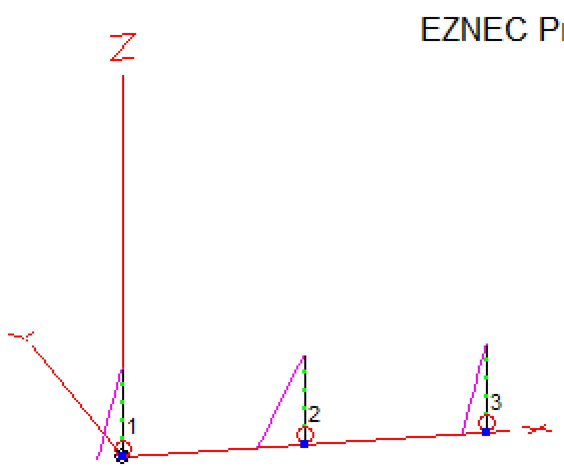


- Average gain= -19.03dBi
- Max gain= -9.95dBi
- **Directivity= 9.08dB**

- The gain is not real as amplifiers will be used. Directivity is correct however.

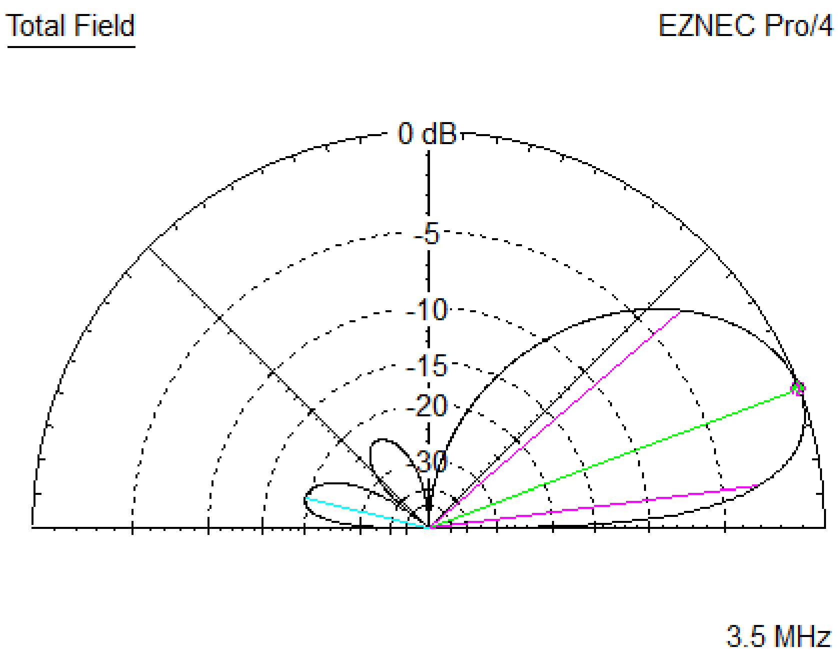
- The same with 16m spacing and 153deg phase shift gives
  - Directivity -13.5—22.99=9.5dB

3 short verticals in line, 3.5MHz

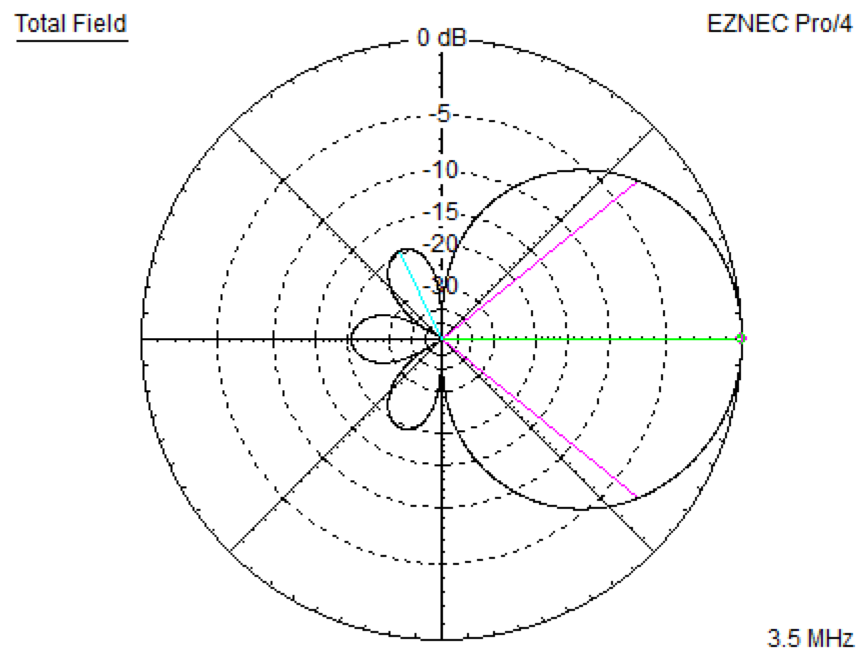


- Verticals 6m high
  - with high impedance pre-amps, ground rod, no radials
- 3 in line, spacing 12m
- Phasing 0/-160/-320 deg
- Current amplitudes 1/1.88/1

3 short verticals in line, 3.5MHz

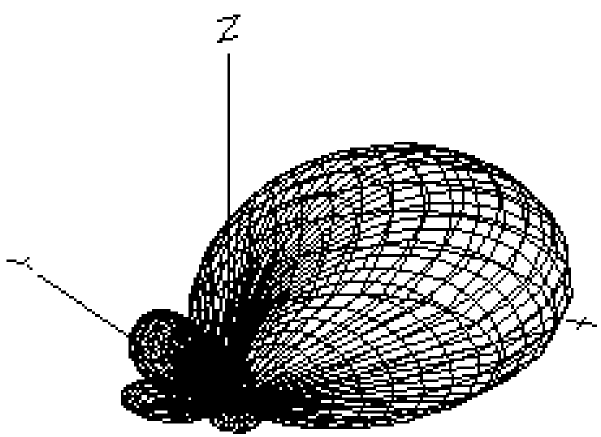


Elevation Plot		Cursor Elev	20.4 deg.
Azimuth Angle	0.0 deg.	Gain	6.91 dBi
Outer Ring	6.91 dBi		0.0 dBmax
Slice Max Gain	6.91 dBi @ Elev Angle = 20.4 deg.		
Beamwidth	33.6 deg.; -3dB @ 7.2, 40.8 deg.		
Sidelobe Gain	-12.62 dBi @ Elev Angle = 166.4 deg.		
Front/Sidelobe	19.53 dB		



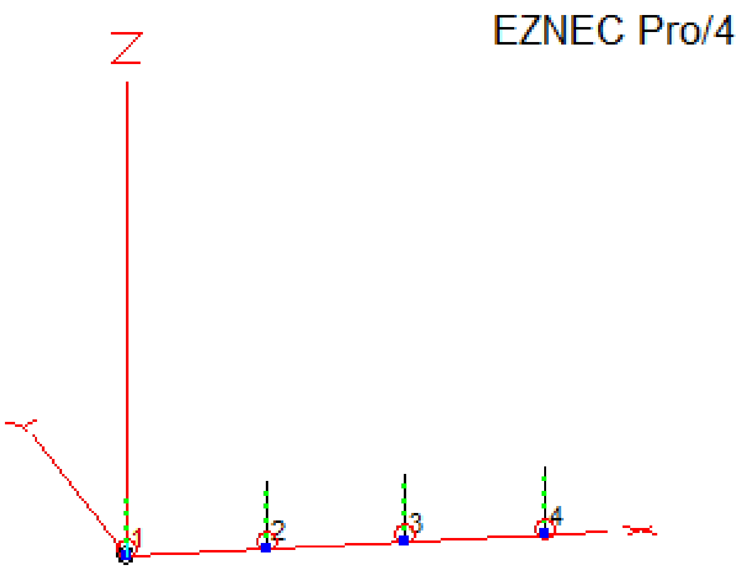
Azimuth Plot		Cursor Az	0.0 deg.
Elevation Angle	20.4 deg.	Gain	6.91 dBi
Outer Ring	6.91 dBi		0.0 dBmax
Slice Max Gain	6.91 dBi @ Az Angle = 0.0 deg.		
Front/Back	20.7 dB		
Beamwidth	78.0 deg.; -3dB @ 321.0, 39.0 deg.		
Sidelobe Gain	-12.35 dBi @ Az Angle = 115.0 deg.		
Front/Sidelobe	19.26 dB		

3 short phased verticals in line, 3.5MHz



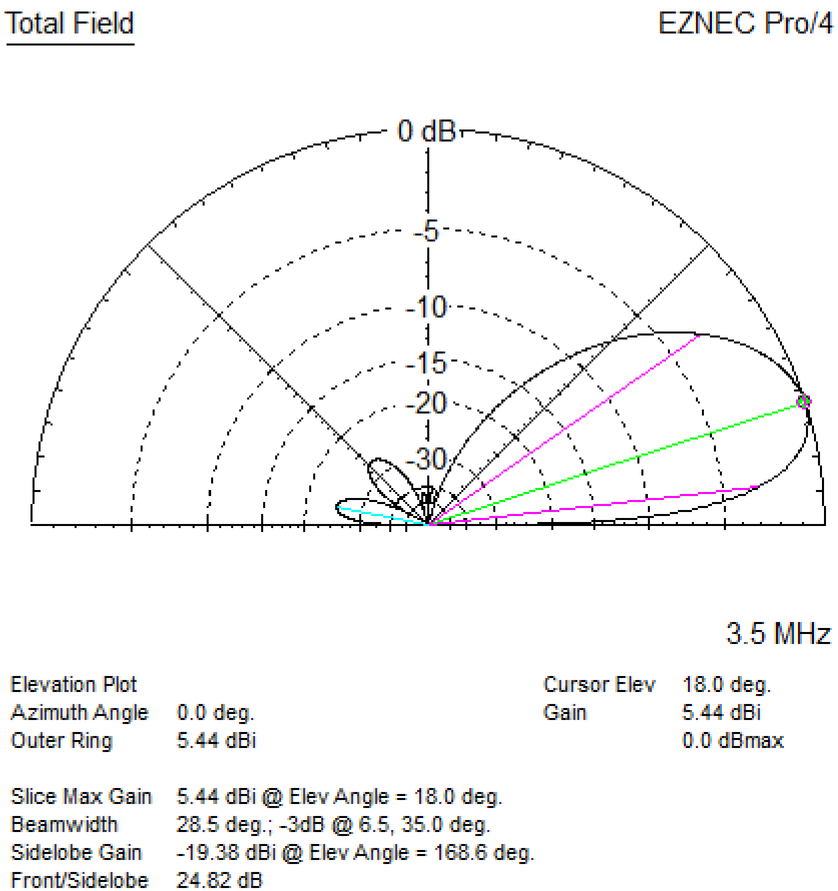
- Average gain -5.4dBi
- Max gain= 6.91dBi @ 20.4 deg
    - The gain is not real as amplifiers will be used. Directivity is correct however.
- **Directivity= 12.31dB**
- When compared to our ¼ wave TX vertical, this 3-el vertical has 12.31-5.38= 6.93dB advantage in directivity

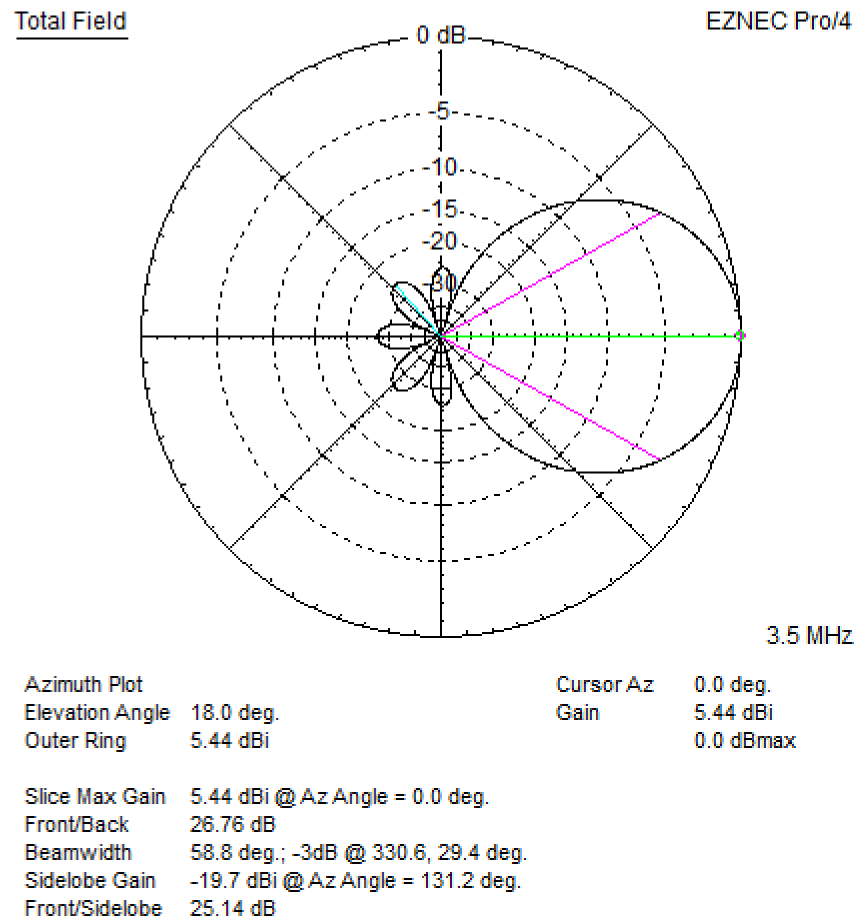
4 short phased vertical in line, 3.5MHz



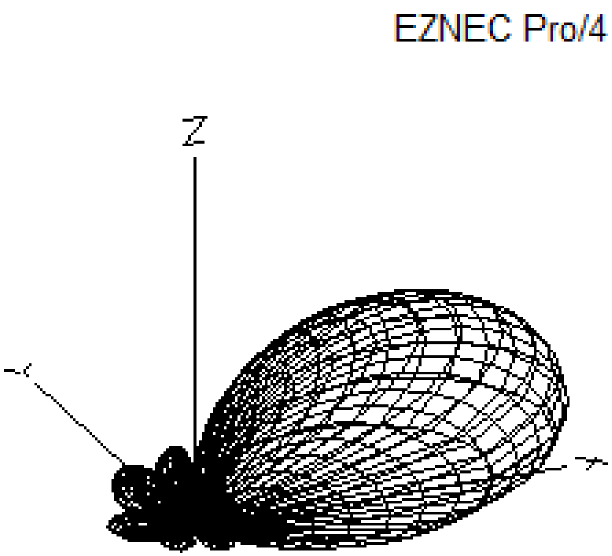
- Verticals 6m high
  - with high impedance pre-amps, ground rod, no radials
- 4 in line, spacing 12m
- Phasing 0/-165/-330/-495 deg
- Current amplitudes 1/2.75/2.75/1

4 short phased vertical in line, 3.5MHz



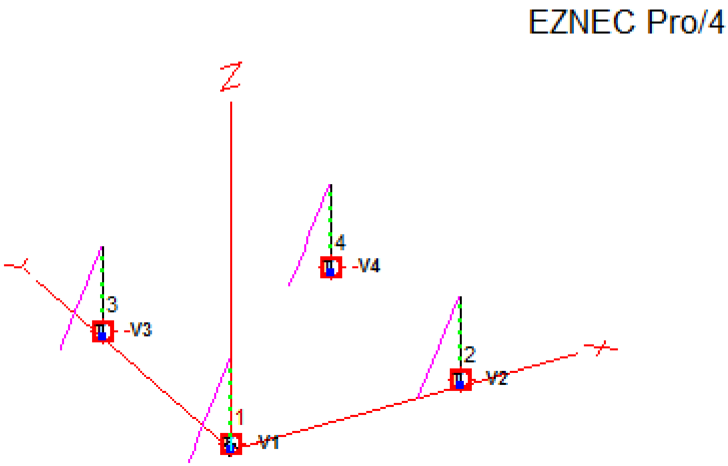


4 short phased vertical in line, 3.5MHz



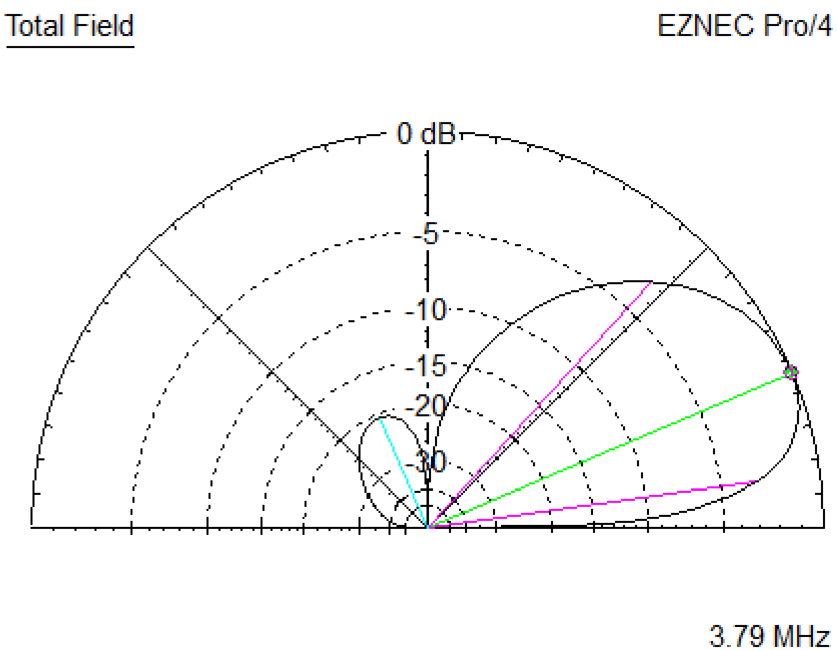
- Average gain -8.68dBi
- Max gain= 5.44dBi @ 18 deg
  - The gain is not real as amplifiers will be used. Directivity is correct however.
- **Directivity= 14.12dB**
  - 0.6dB better than Beverage
- When compared to our ¼ wave TX vertical, this 4-el vertical has 14.12-5.38= 8.74dB advantage in directivity

RX-4SQ, 3.79MHz



- Verticals 6m high
  - with high impedance pre-amps, ground rod, no radials
- Spacing 15x15m
- Phasing 0/-122/-122/-244
- Current amplitudes 1/1/1/1

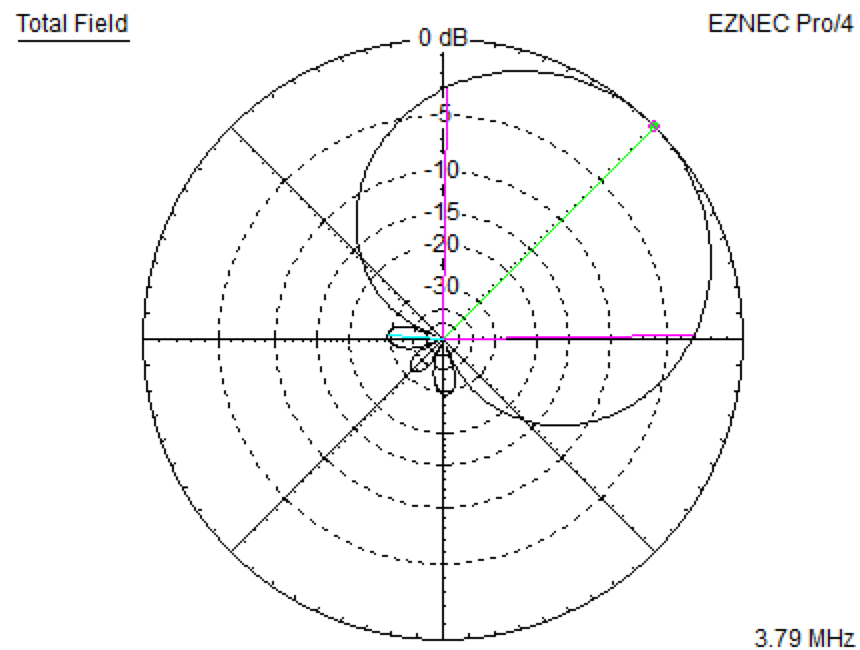
RX-4SQ, 3.79MHz



Elevation Plot
Azimuth Angle 45.0 deg.
Outer Ring 6.65 dBi

Cursor Elev 23.0 deg.
Gain 6.65 dBi
0.0 dBmax

Slice Max Gain 6.65 dBi @ Elev Angle = 23.0 deg.
Beamwidth 39.7 deg.; -3dB @ 7.9, 47.6 deg.
Sidelobe Gain -13.88 dBi @ Elev Angle = 114.0 deg.
Front/Sidelobe 20.53 dB

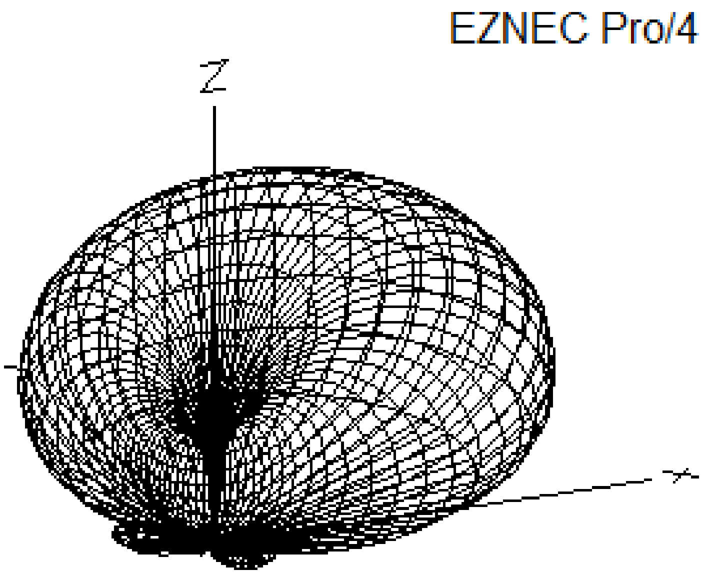


Azimuth Plot
Elevation Angle 23.0 deg.
Outer Ring 6.65 dBi

Cursor Az 45.0 deg.
Gain 6.65 dBi
0.0 dBmax

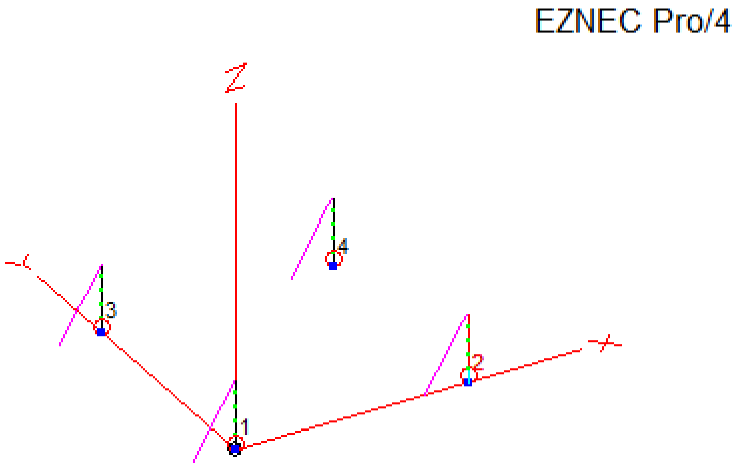
Slice Max Gain 6.65 dBi @ Az Angle = 45.0 deg.
Front/Back 33.0 dB
Beamwidth 87.8 deg.; -3dB @ 1.1, 88.9 deg.
Sidelobe Gain -22.34 dBi @ Az Angle = 176.0 deg.
Front/Sidelobe 28.99 dB

RX-4SQ, 3.79MHz



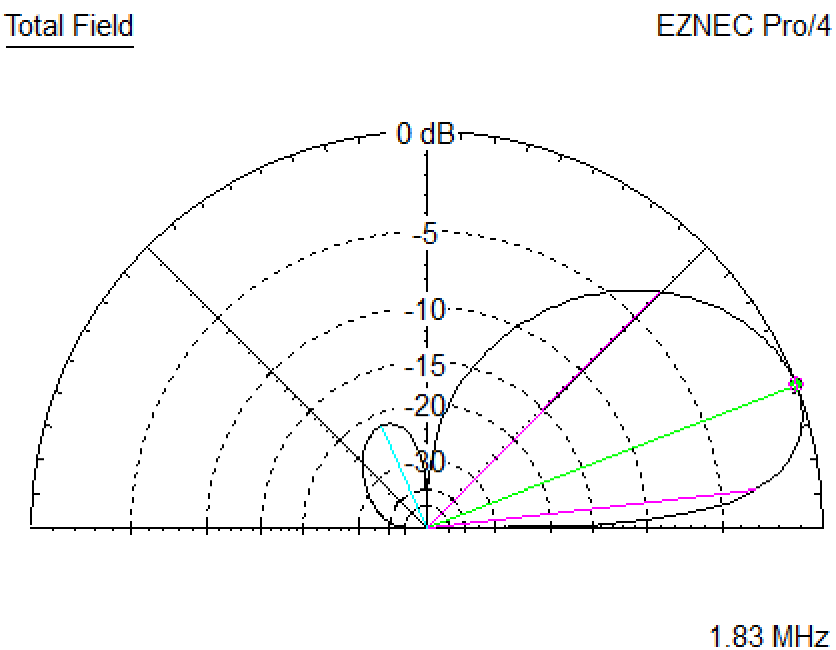
- Average gain= -4.47dBi
- Gain = 6.65dBi
  - The gain is not real as amplifiers will be used. Directivity is correct however.
- **Directivity= 11.12dB**

RX-4SQ, 1.83MHz



- Verticals 6m high
  - with high impedance pre-amps, ground rod, no radials
- Spacing 20x20m
- Phasing 0/-142/142/-284deg
- Current amplitudes 1/1/1/1
- Normal ground

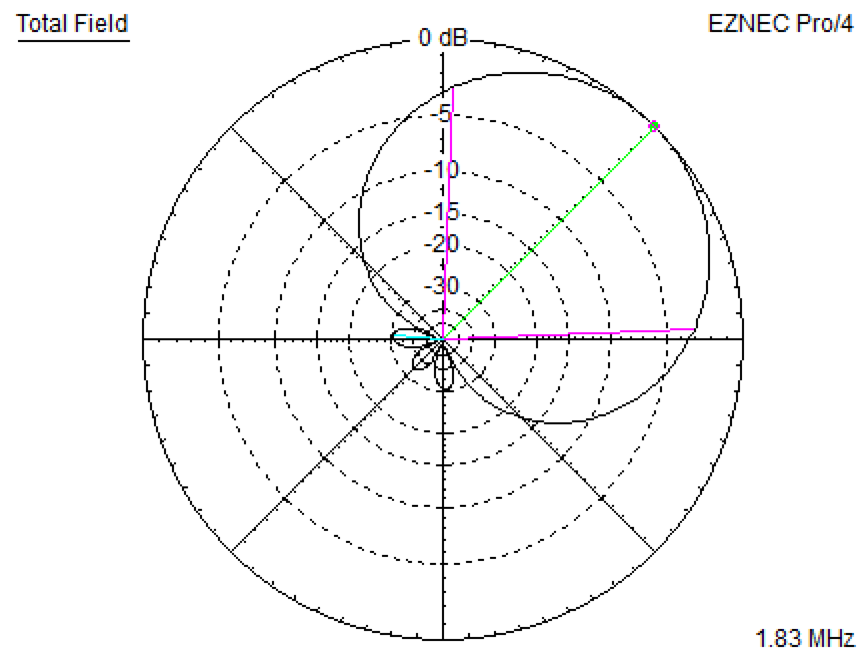
RX-4SQ, 1.83MHz



Elevation Plot
Azimuth Angle 45.0 deg.
Outer Ring 6.2 dBi

Cursor Elev 21.0 deg.
Gain 6.2 dBi
0.0 dBmax

Slice Max Gain 6.2 dBi @ Elev Angle = 21.0 deg.
Beamwidth 38.5 deg.; -3dB @ 6.6, 45.1 deg.
Sidelobe Gain -15.61 dBi @ Elev Angle = 114.0 deg.
Front/Sidelobe 21.81 dB

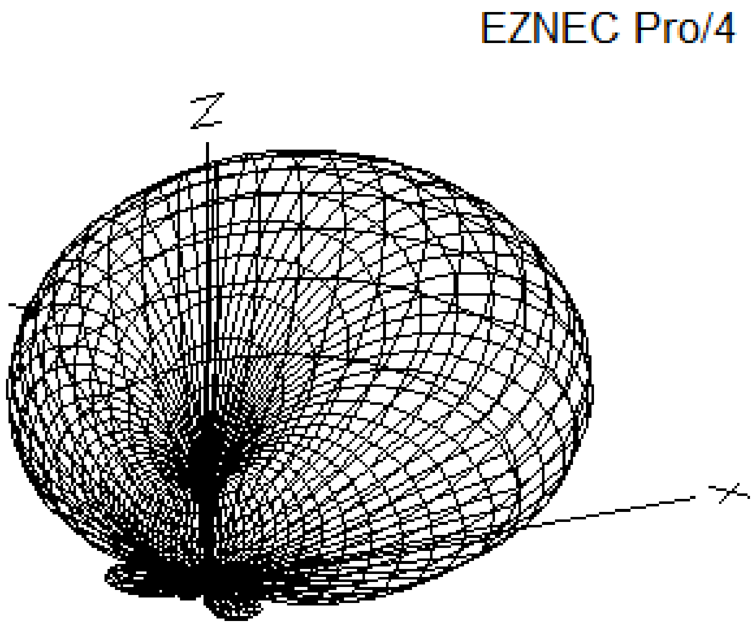


Azimuth Plot
Elevation Angle 21.0 deg.
Outer Ring 6.2 dBi

Cursor Az 45.0 deg.
Gain 6.2 dBi
0.0 dBmax

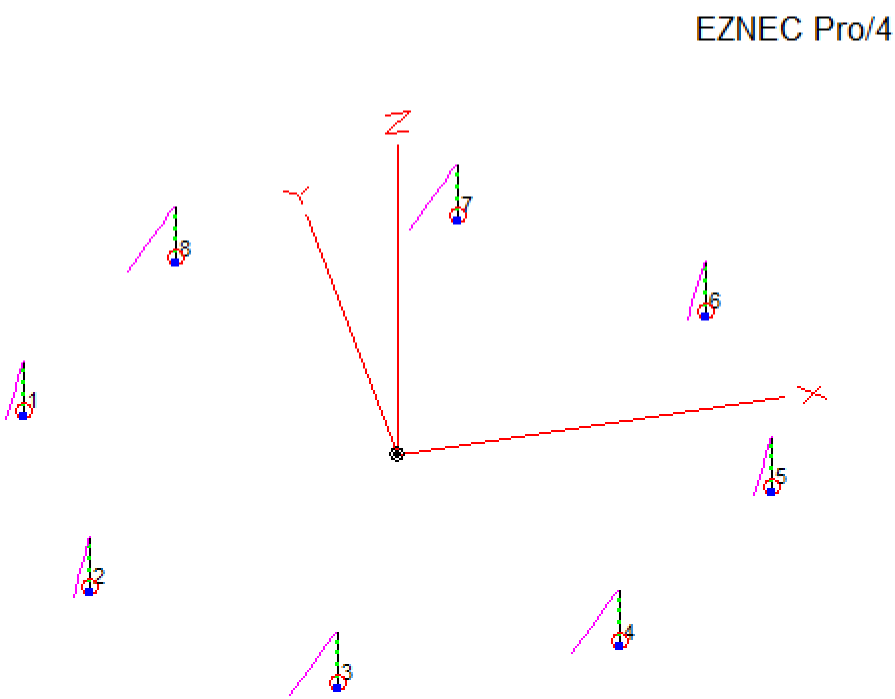
Slice Max Gain 6.2 dBi @ Az Angle = 45.0 deg.
Front/Back 33.97 dB
Beamwidth 85.4 deg.; -3dB @ 2.3, 87.7 deg.
Sidelobe Gain -24.42 dBi @ Az Angle = 176.0 deg.
Front/Sidelobe 30.62 dB

RX-4SQ, 1.83MHz



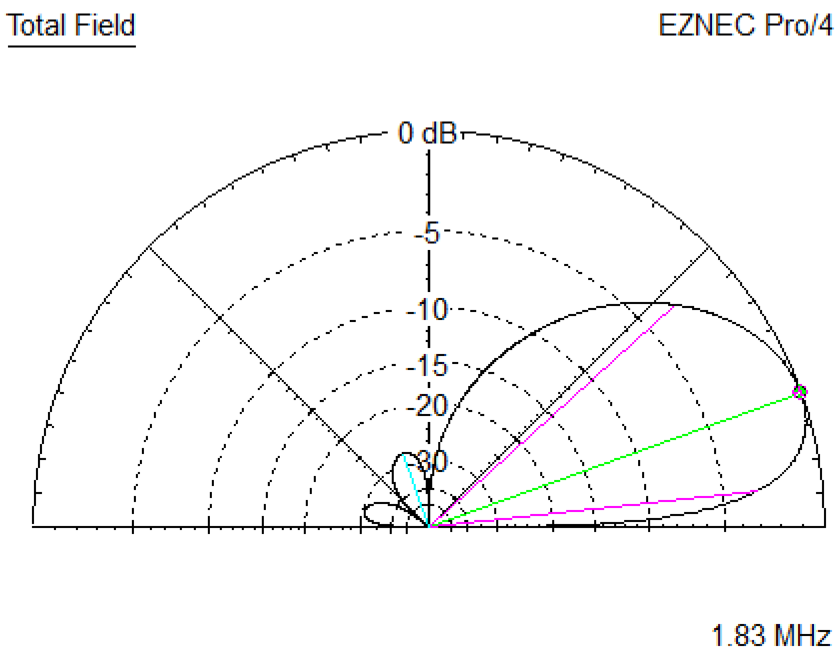
- Average gain= -5.08dBi
- Gain= 6.2dBi
  - The gain is not real as amplifiers will be used. Directivity is correct however.
- **Directivity= 11.28dB**

8 circle array, 1.83MHz



- Circle radius 30.5m
- Each vertical 6m high
  - with high impedance pre-amps, ground rod, no radials
- Current amplitudes 1.07/3/3/1.07
  - by pairs
- Phasing 0/-149/-286/-435 deg
  - by pairs
- Switchable to 8 directions
  - 45 deg sectors
  - gain variation 2dB over 360deg azimuth

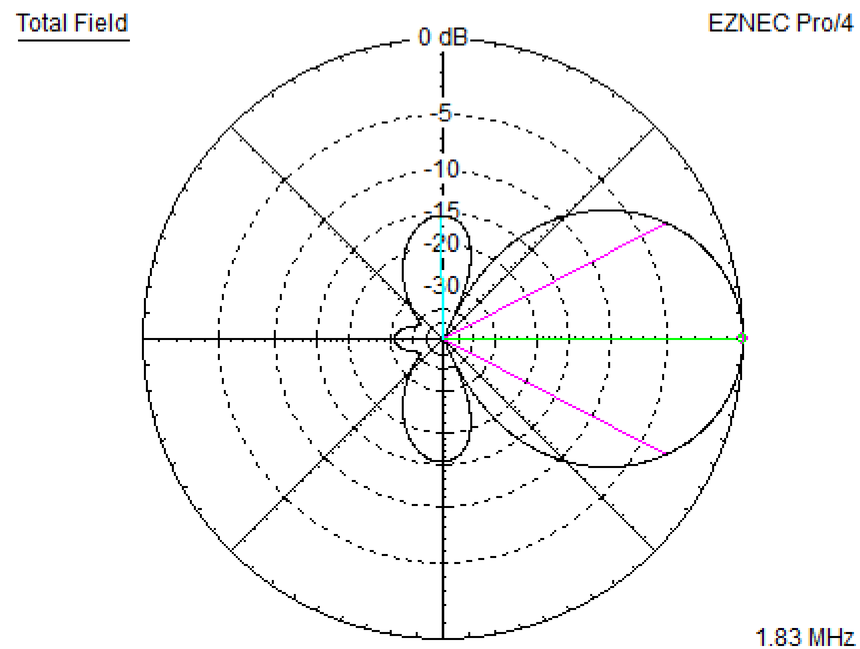
8 circle array, 1.83MHz



Elevation Plot
Azimuth Angle 0.0 deg.
Outer Ring 8.78 dBi

Cursor Elev 19.8 deg.
Gain 8.78 dBi
0.0 dBmax

Slice Max Gain 8.78 dBi @ Elev Angle = 19.8 deg.
Beamwidth 35.6 deg.; -3dB @ 6.4, 42.0 deg.
Sidelobe Gain -19.19 dBi @ Elev Angle = 109.2 deg.
Front/Sidelobe 27.97 dB

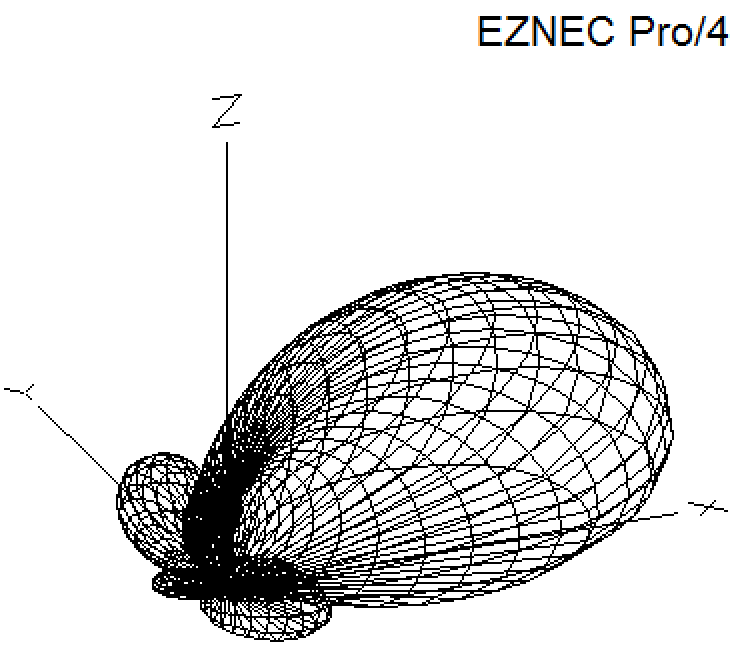


Azimuth Plot
Elevation Angle 19.8 deg.
Outer Ring 8.78 dBi

Cursor Az 0.0 deg.
Gain 8.78 dBi
0.0 dBmax

Slice Max Gain 8.78 dBi @ Az Angle = 0.0 deg.
Front/Back 31.5 dB
Beamwidth 54.4 deg.; -3dB @ 332.8, 27.2 deg.
Sidelobe Gain -6.53 dBi @ Az Angle = 90.6 deg.
Front/Sidelobe 15.31 dB

8 circle array, 1.83MHz

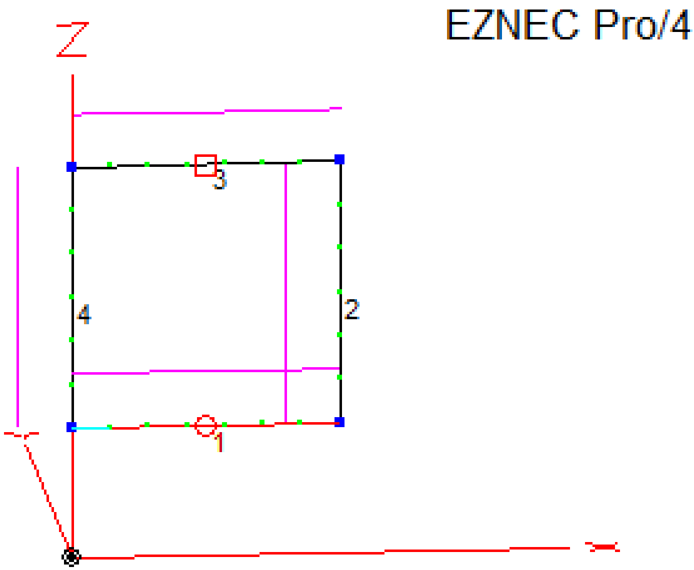


- Average gain= -4.59dBi
- Max gain= 8.78dBi @ 19.8 deg
  - The gain is not real as amplifiers will be used. Directivity is correct however.
- **Directivity= 13.37dB**
  - Beverage level

5. Other antennas

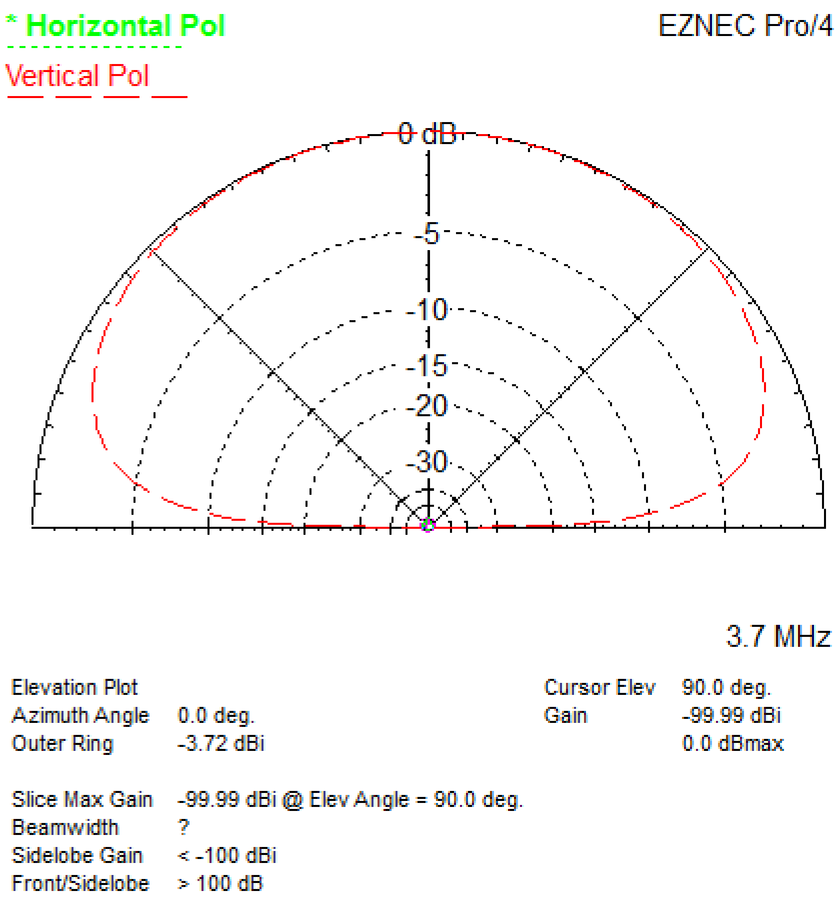
Magnetic loop

Magnetic loop 3.7MHz



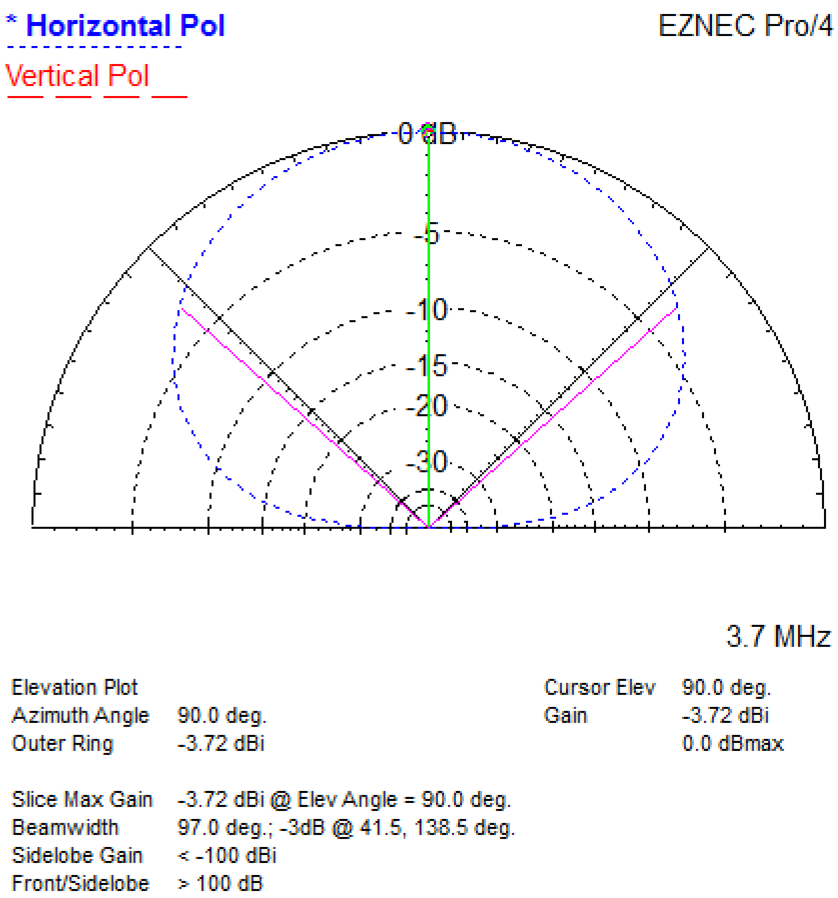
- Size 2x2m dia35mm copper tube
- Tuned to resonance 282pF serial capacitor
- Lower wire 1 is 1m above the ground
- Almost constant current distribution as seen on the left.
- Receives vertical and horizontal polarization in different ways, which makes it problematic in DX-operation

Magnetic loop 3.7MHz, radiation pattern on X-axis



- Vertical polarization:
  - Gain -3.72dBi @ 90 deg
- Horizontal polarization:
  - Gain -99dBi
- Normal ground

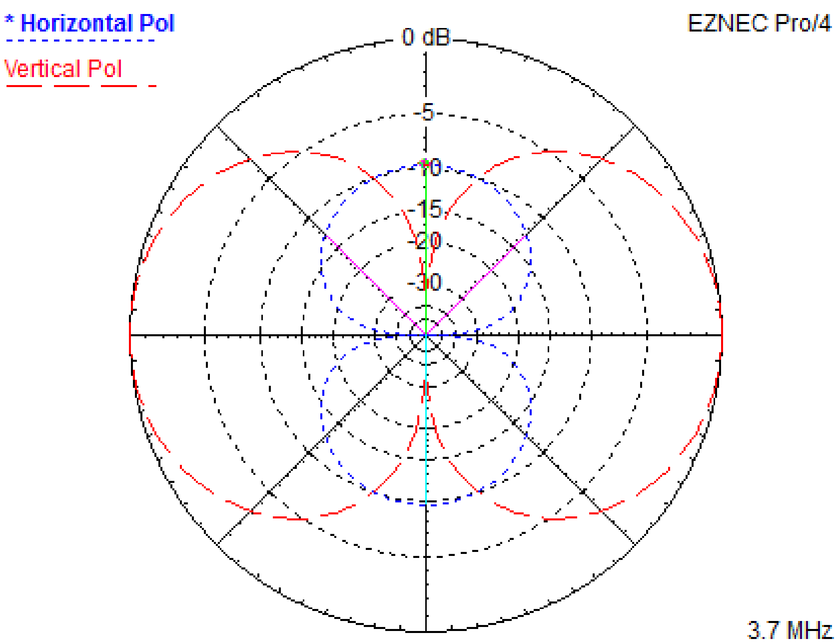
Magnetic loop 3.7MHz, radiation pattern on Y-axis



- Vertical polarization:
  - Gain -99dBi
- Horizontal polarization:
  - Gain -3.72dBi @ 90 deg
- Normal ground

Magnetic loop 3.7MHz, at 10 and 20 deg elevation angles

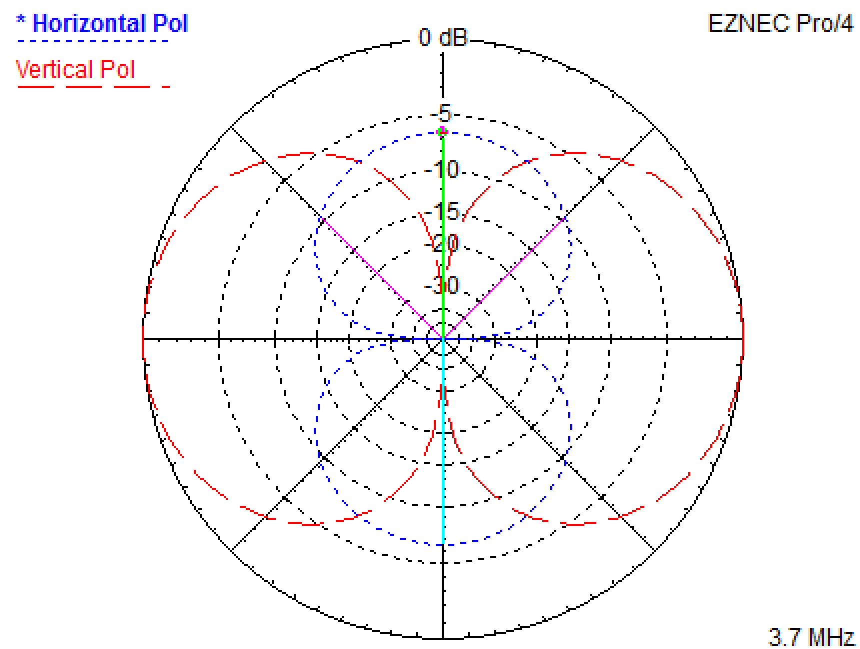
10 deg elevation



Azimuth Plot		Cursor Az	90.0 deg.
Elevation Angle	10.0 deg.	Gain	-17.59 dBi
Outer Ring	-8.01 dBi		0.0 dBmax

Slice Max Gain	-17.59 dBi @ Az Angle = 90.0 deg.
Front/Side	82.4 dB
Beamwidth	89.8 deg.; -3dB @ 45.1, 134.9 deg.
Sidelobe Gain	-17.59 dBi @ Az Angle = 270.0 deg.
Front/Sidelobe	0.0 dB

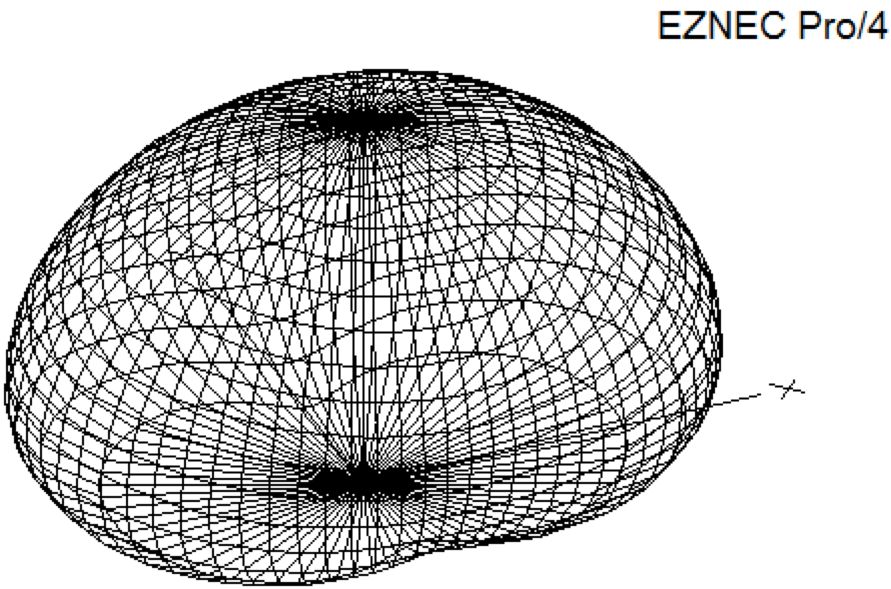
20 deg elevation



Azimuth Plot		Cursor Az	90.0 deg.
Elevation Angle	20.0 deg.	Gain	-11.96 dBi
Outer Ring	-5.5 dBi		0.0 dBmax

Slice Max Gain	-11.96 dBi @ Az Angle = 90.0 deg.
Front/Side	88.03 dB
Beamwidth	89.8 deg.; -3dB @ 45.1, 134.9 deg.
Sidelobe Gain	-11.96 dBi @ Az Angle = 270.0 deg.
Front/Sidelobe	0.0 dB

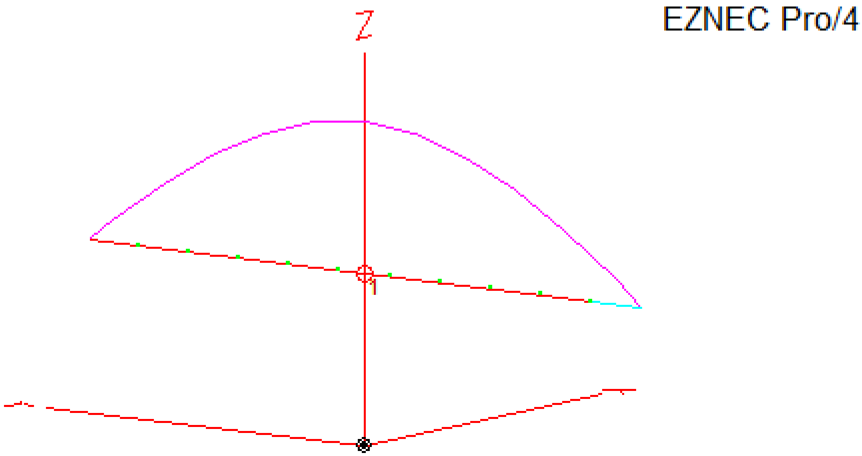
Magnetic loop 3.7MHz, total field



- Max gain= -3.72dBi @ 90 deg
- Average gain= -9.43dBi
- **Directivity= 5.7dB**

- This picture illustrates DX-reception, because polarization varies on HF in ionospheric reflections
- Magnetic loop can be directive in near field and on VHF, where polarization is fixed and stable.
- But it is not directive antenna for low band contesting or DXing

Low dipole on 1.83MHz

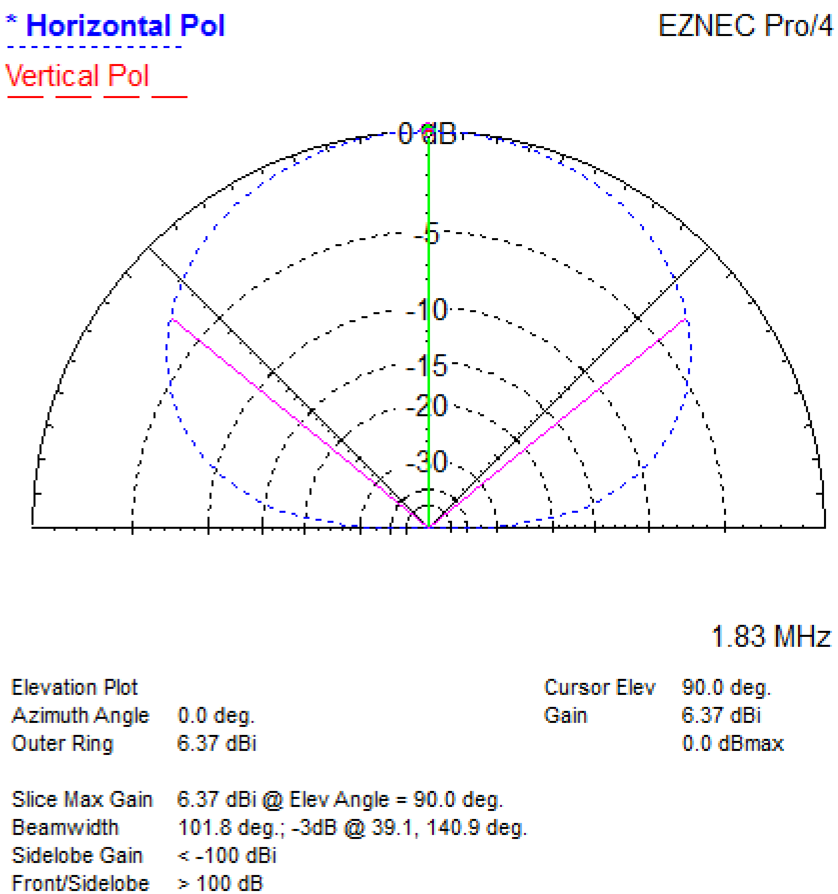


- Many times I have heard people saying that low dipole is good for 160m reception. Is it?
- Height 20m, normal ground
- Average gain= -1.94dBi
- Max gain= 6.37dBi @ 90deg
- **Directivity= 8.3dB,** but wrong direction

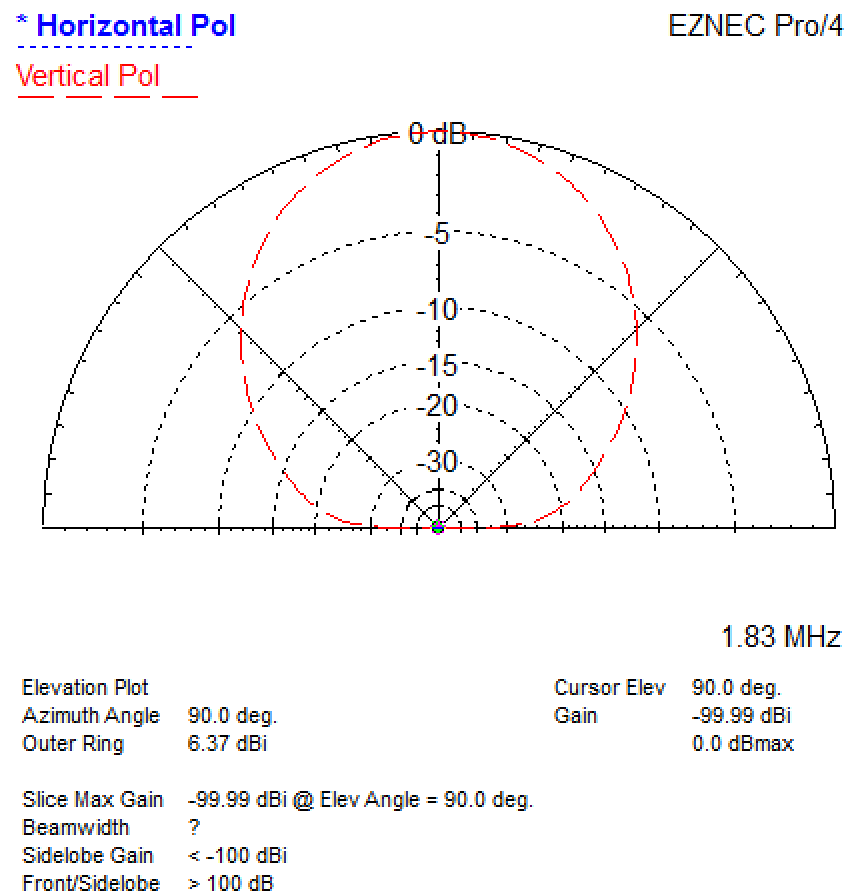
- No way to be good receiving antenna

Low dipole on 1.83MHz

On X-axis



On Y-axis



Conclusions

- Beverage is still a strong performer in receiving low band signals
  - If you have the space, use them!
- Loop-like travelling wave antennas K9AY, Flag, EWE
  - Take off angle is too high
  - Need a good preamplifier
  - Performance is only modest
  - > Not my choice
- Phased short vertical arrays with pre-amps at each element
  - Good performance
  - Different configurations possible
  - Phasing easy to arrange
  - Fit to smaller space than Beverage
  - > My next project