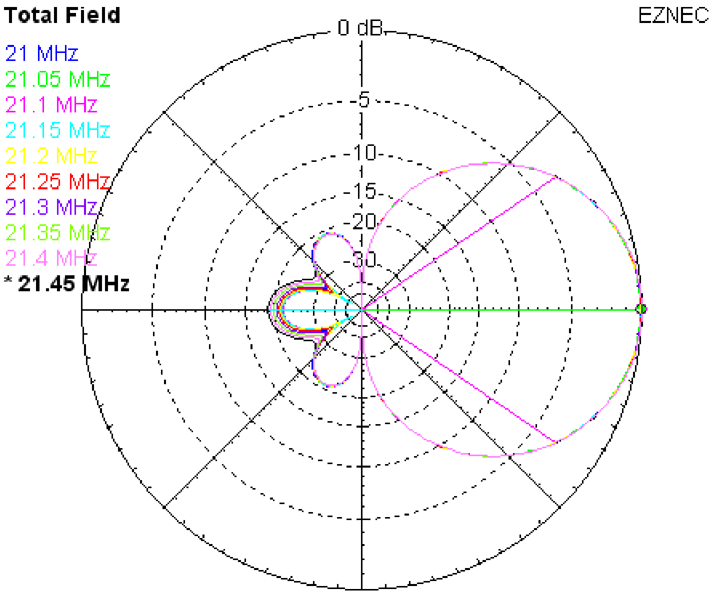


Pekka Ketonen
OH1TV OH1O OH1WX

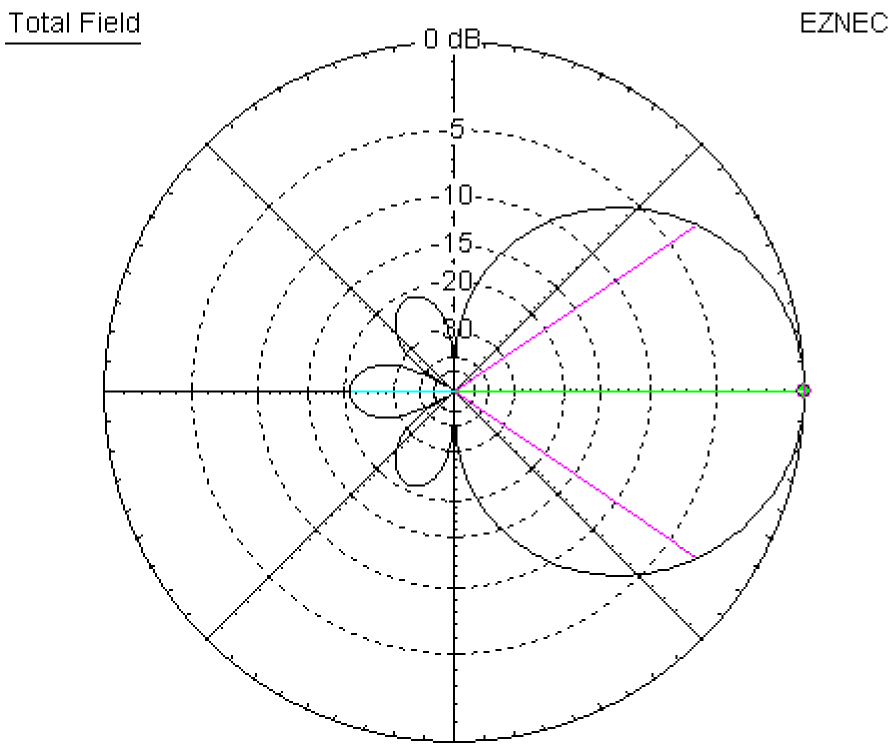
Opposite Voltages Fed Two Element Array

Opposite voltages fed two element array

Advantages

- Wideband
  - Gain pattern variation is small
    - Forward gain 6.4-6.5dBi on 15m band 21.000-21.450 MHz
    - F/B > 20dB
  - Good SWR , typical SWR < 1.5
- Straight elements
- Good for low bands
- Multiband operation with equal performance possible by switching.
  - Feedpoint impedance change however.

Gain pattern on center frequency

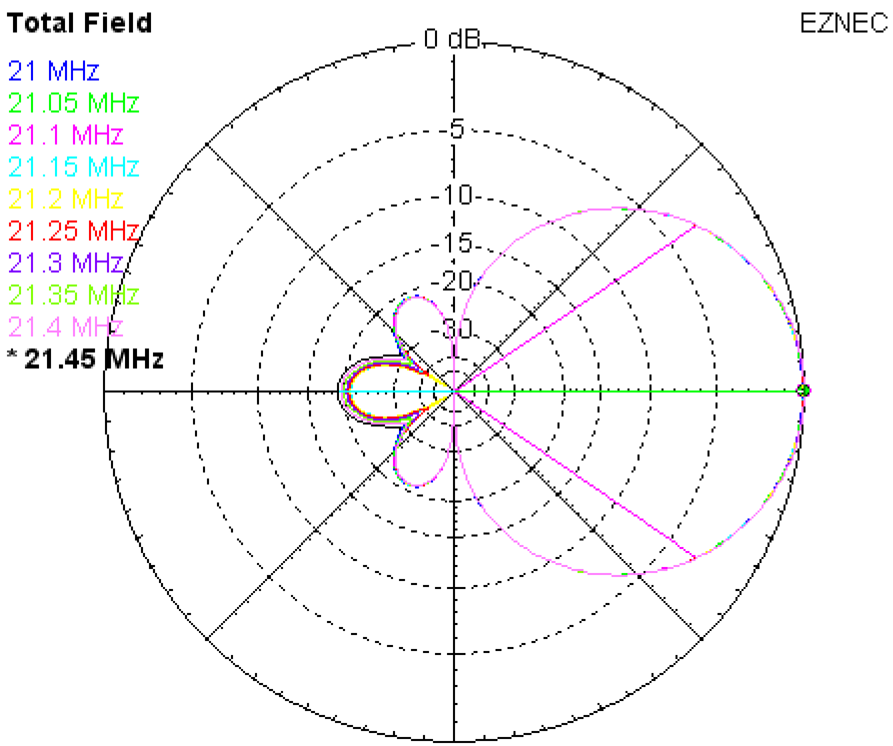


Azimuth Plot		Cursor Az	0.0 deg.
Elevation Angle	0.0 deg.	Gain	6.5 dBi
Outer Ring	6.5 dBi		0.0 dBmax

Slice Max Gain	6.5 dBi @ Az Angle = 0.0 deg.
Front/Back	20.82 dB
Beamwidth	69.0 deg.; -3dB @ 325.5, 34.5 deg.
Sidelobe Gain	-14.32 dBi @ Az Angle = 180.0 deg.
Front/Sidelobe	20.82 dB

Gain pattern variation on 15m band

Inter-element cable

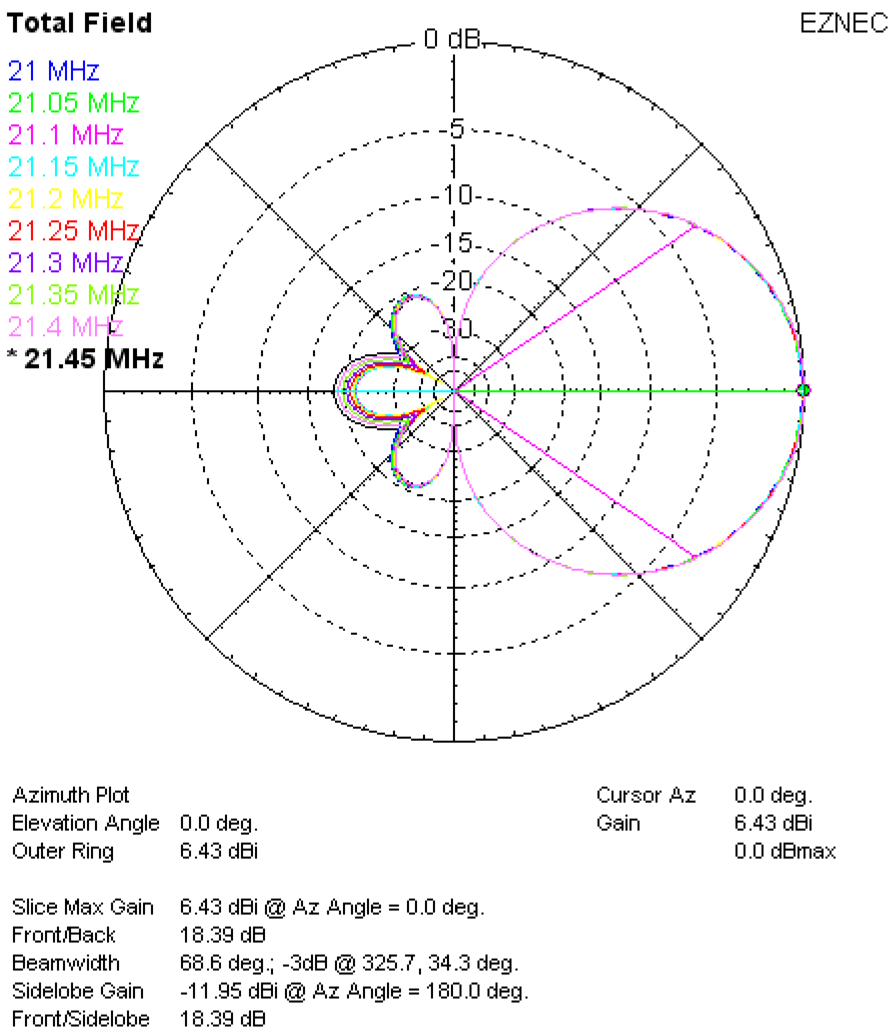


Azimuth Plot		Cursor Az	0.0 deg.
Elevation Angle	0.0 deg.	Gain	6.53 dBi
Outer Ring	6.53 dBi		0.0 dBmax

Slice Max Gain	6.53 dBi @ Az Angle = 0.0 deg.
Front/Back	18.92 dB
Beamwidth	68.8 deg.; -3dB @ 325.6, 34.4 deg.
Sidelobe Gain	-12.39 dBi @ Az Angle = 180.0 deg.
Front/Sidelobe	18.92 dB

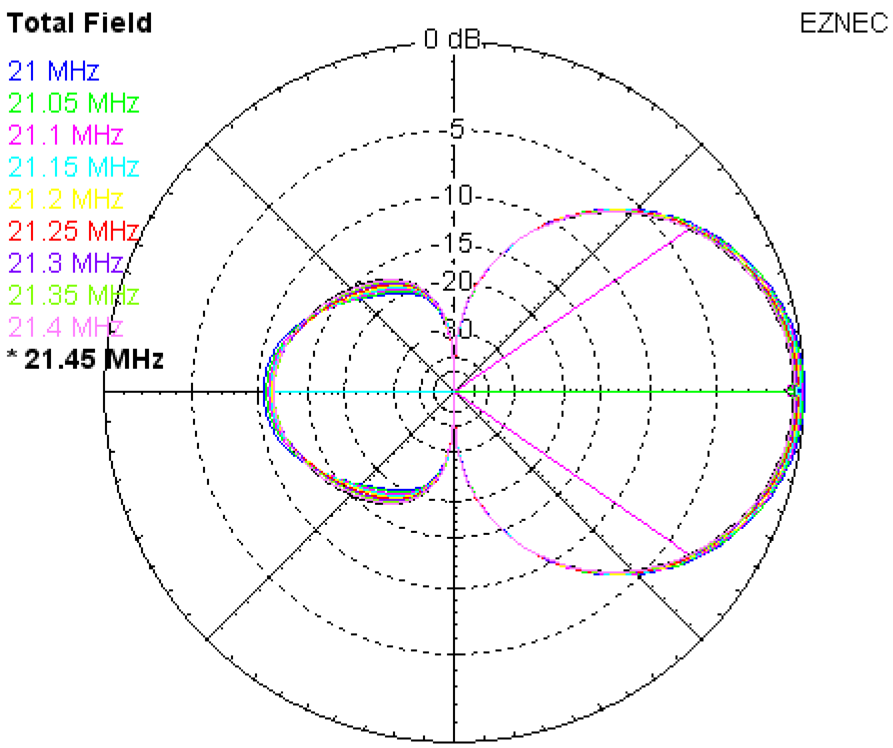
Gain pattern variation on 15m band

With two cables



Traditional parasitic yagi

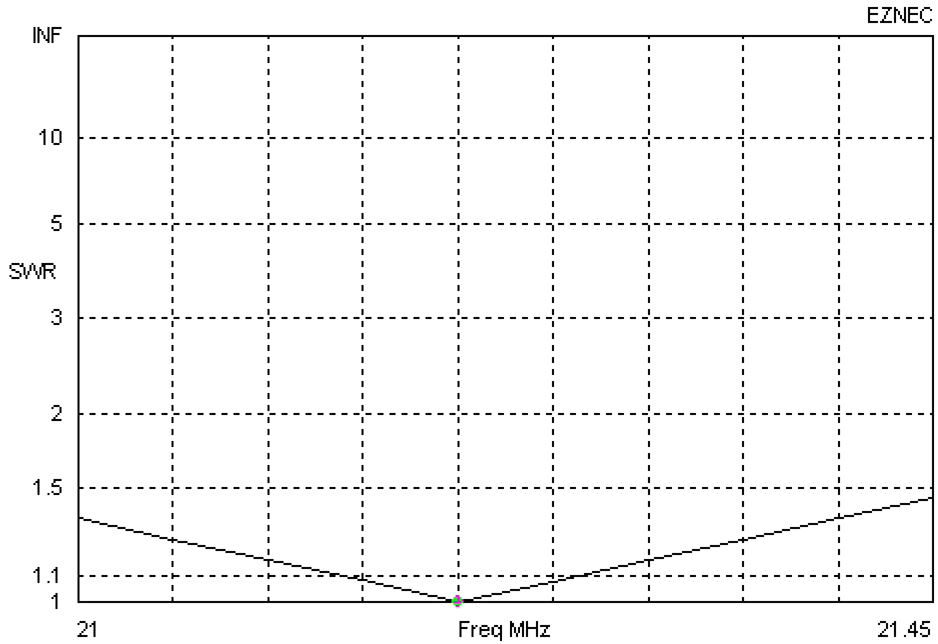
Gain pattern variation on 15m band



Azimuth Plot		Cursor Az	0.0 deg.
Elevation Angle	0.0 deg.	Gain	5.96 dBi
Outer Ring	6.51 dBi		0.0 dBmax

Slice Max Gain	5.96 dBi @ Az Angle = 0.0 deg.
Front/Back	10.77 dB
Beamwidth	69.8 deg.; -3dB @ 325.1, 34.9 deg.
Sidelobe Gain	-4.81 dBi @ Az Angle = 180.0 deg.
Front/Sidelobe	10.77 dB

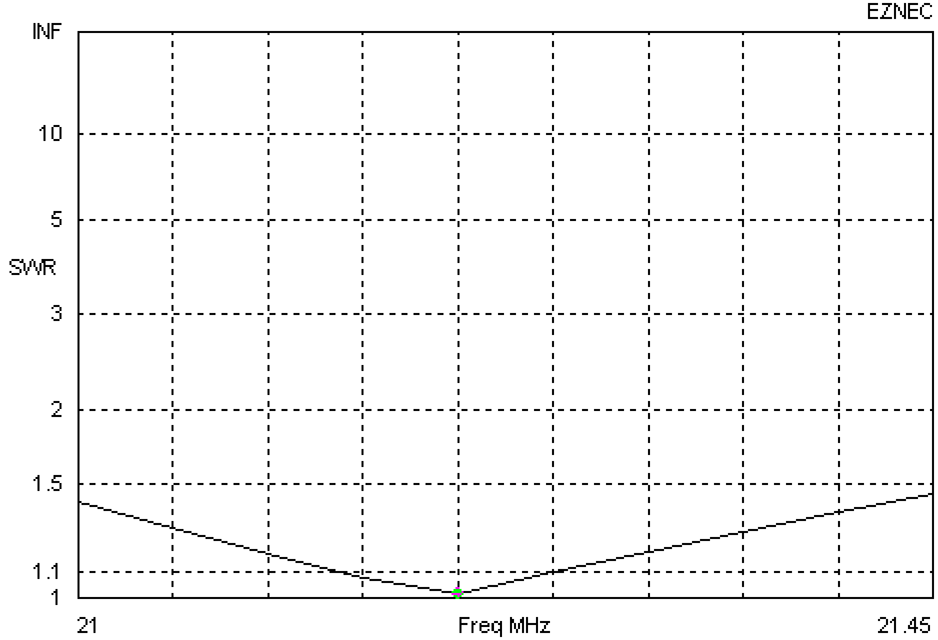
SWR on 15m band, L-match used



Freq	21.2 MHz	Source #	1
SWR	**1.003**	Z0	50 ohms
Z	50.01 at 0.18 deg.		
	= 50.01 + j 0.1564 ohms		
Refl Coeff	0.001571 at 84.57 deg.		
	= 0.0001486 + j 0.001564		
Ret Loss	56.1 dB		

Traditional parasitic yagi

SWR on 15m band, L-match used



Freq	21.2 MHz	Source #	1
SWR	**1.011**	Z0	50 ohms
Z	50.54 at 0.01 deg.		
	= 50.54 + j 0.01306 ohms		
Refl Coeff	0.005402 at 1.37 deg.		
	= 0.0054 + j 0.0001292		
Ret Loss	45.3 dB		

Eznec description

15m band, with inter-element cable

EZNEC ver. 5.0

2FB21 50 ohm välikaapeli 9.2.2009 19:43:42

--------------- ANTENNA DESCRIPTION ---------------

Frequency = 21.2 MHz
Wire Loss: Aluminum (6061-T6) -- Resistivity = 4E-08 ohm-m, Rel. Perm. = 1

--------------- WIRES ---------------

No.	End 1 Conn.	End 1 Coord. (m) X	End 1 Y	End 1 Z	End 2 Conn.	End 2 Coord. (m) X	End 2 Y	End 2 Z	Dia (mm)	Segs	Insulation Diel C	Insulation Thk(mm)
1		2,	-3.23,	0		2,	3.23,	0	12	11	1	0
2		0,	-3.565,	0		0,	3.565,	0	12	11	1	0

Total Segments: 22

-------------- SOURCES --------------

No.	Specified Pos. Wire #	Specified Pos. % From E1	Actual Pos. % From E1	Actual Pos. Seg	Amplitude (V/A)	Phase (deg.)	Type
1	V1	0.00	0.00		1	0	I

No loads specified

-------- TRANSMISSION LINES ---------

No.	End 1 Specified Pos Wire #	End 1 Specified Pos % From E1	End 1 Act % From E1	End 2 Specified Pos Wire #	End 2 Specified Pos % From E1	End 2 Act % From E1	Length (m)	Z0 (ohms)	VF	Loss (dB/100 m)	Loss Freq (MHz)	Rev/Norm
1	1	50.00	50.00	2	50.00	50.00	5.3	50	0.75	4	100	N

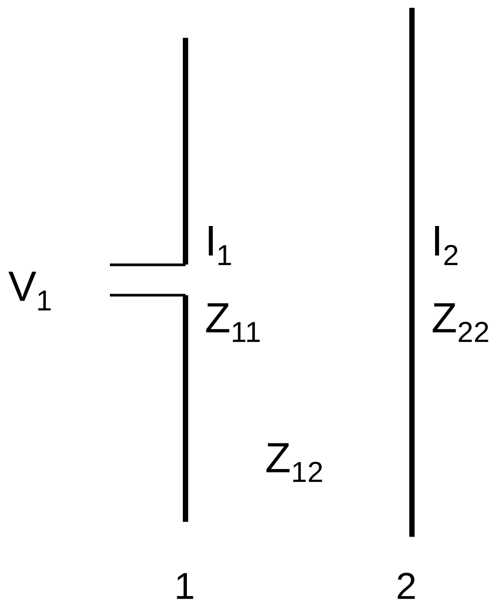
No transformers specified

-------------- L NETWORKS (RLC Type) --------------

No.	Specified Pos. Port 1 Wire # / Port 2 Wire #	Specified Pos. Port 1 % From E1 / Port 2 % From E1	Actual Pos. % From E1	Actual Pos. Seg	R(ohms) Ser Br / Sh Br	L(uH) Ser Br / Sh Br	C(pF) Ser Br / Sh Br	R Freq(MHz) Ser Br / Sh Br	Type Ser Br / Sh Br
1	1	50.00	50.00	6	Short	0.16	Short	0	Ser
	V1	0.00	0.00		Short	Short	217	0	Ser

Ground type is Free Space

Traditional parasitic two element yagi



Z_{11} = self impedance of element 1

Z_{22} = self impedance of element 2

Z_{12} = mutual impedance of elements 1 and 2

I_1 = current in element 1

I_2 = current in element 2

V_1 = voltage at feed point

The circuit relations for the elements are:

$$V_1 = I_1 Z_{11} + I_2 Z_{12}$$

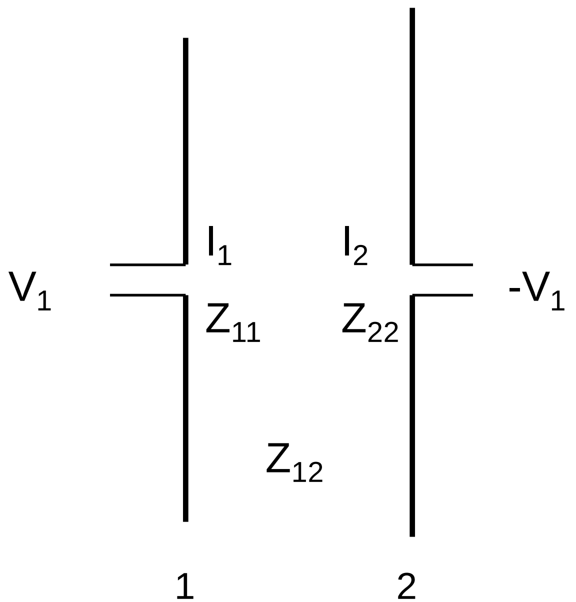
$$0 = I_2 Z_{22} + I_1 Z_{12}$$

- $I_2 = - I_1 * (Z_{12} / Z_{22})$ source: Kraus, Antennas

- Phase difference of element currents is
  - strongly dependent on element 2 detuning (Z_{22})
  - independent of element 1 detuning (Z_{11})
  - dependent on mutual impedance Z_{12} , which is quite insensitive to frequency change however

- Gain pattern is frequency sensitive
- F/B is good only on narrow band width

Opposite voltages fed two element array



Z_{11} = self impedance of element 1

Z_{22} = self impedance of element 2

Z_{12} = mutual impedance of elements 1 and 2

I_1 = current in element 1

I_2 = current in element 2

V_1 = voltage at feed point

The circuit relations for the elements are:

$V_1 = I_1 Z_{11} + I_2 Z_{12}$

$-V_1 = I_2 Z_{22} + I_1 Z_{12}$

- $I_2 = - I_1 * (Z_{11} + Z_{12}) / (Z_{22} + Z_{12})$

- Phase shift I_2 / I_1 depends on all Z's
  - Angle difference of Z_{11} and Z_{22} vary slowly as function of frequency
  - Z_{12} is quite insensitive to frequency change and is present on both sides of the divider
- Amplitudes of currents I_1 and I_2 become almost the same

- Gain pattern is quite insensitive to frequency change.
- Good F/B over wide frequency band is possible

How to do it?

- Both elements are voltage driven, in opposite phase.
  - From the feedpoint of element 1 (“driven”) there is a ½ wavelength cable (electrical wavelength) to the feedpoint of element 2 (“reflector).
    - No reversal of cable polarity is used.
    - Voltage at element 2 feedpoint is 180 degrees from element 1 feedpoint voltage.
      - In traditional parasitic yagi element 2 voltage is zero.
  - An alternative way is to bring ½ wavelength cables from the antenna feedpoint to both elements.
    - Connection to elements is in opposite polarity.
    - In the antenna feedpoint the cables are connected parallel.
  - Suitable impedance for the phasing cable is 50 ohm.
  - Element currents depend on their detuning and are not in phase with their feedpoint voltages
- Element detuning is used for current phasing
  - Dimensions are different in comparison to traditional 2-element yagi.
    - “Reflector” becomes longer and “driven element” shorter.
- Antenna feedpoint resistance becomes 17-27 ohm, depending on boom length
  - Reactive part tend to be a bit inductive
  - Matching to 50 ohm is easy with low-pass L-match
    - the inductive component becomes part of the matching circuit.
- Element 2 can be a “reflector” or “director”.
  - 180 degree direction switching is possible when detuning is done with lumped components
- Antenna can be optimized for a certain hight
- Eznec 5 handles this antenna ok.

Is it phased array or log-periodic ?

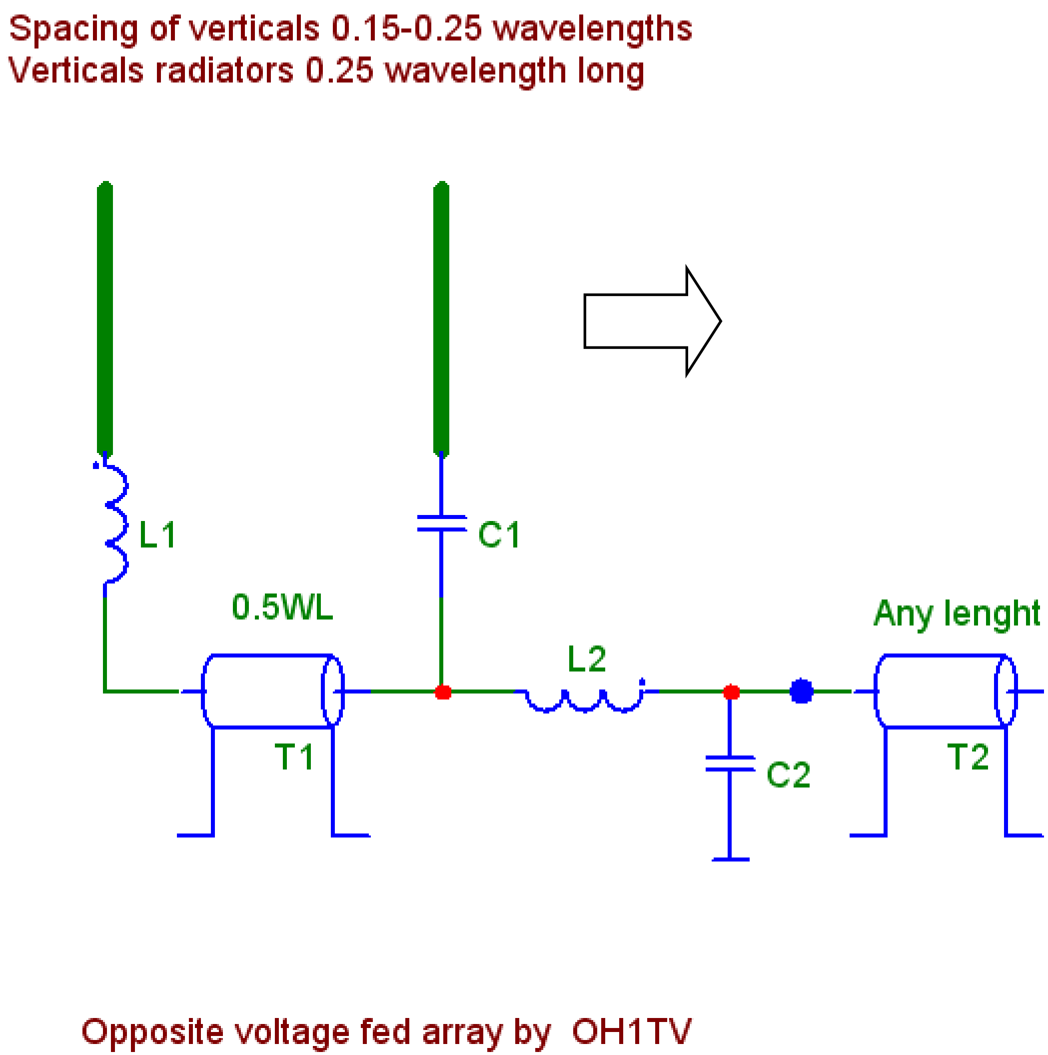
- In phased array
  - Antenna elements are equal in size.
    - Detuning of elements is not used to control current relations
  - Separate phasing unit is used to control currents relations
  - Feed from the phasing unit to the elements is with current forcing
    - ¼ + n* ½ (n=0,1,2..) wavelength long cables are used.
- In log-periodic antenna
  - Elements are different in size
    - Detuning of elements mainly dictate currents relations
  - Each element is fed.
    - Length of feed-line from next element is the actual distance.
    - Electrical length of the feed-line is (180 deg (inversion) – actual length in wavelength degrees)
- In this antenna “phasing” means, that
  - Equal but opposite polarity voltages are brought to the elements.
    - 1/2 wavelength cable can be used between the elements for the inversion and “voltage forcing”
    - or both elements are fed with ½ wavelength cables but connections to elements are in opposite polarity
  - Current phase relations are created by detuning both elements
    - one below the resonance and the other above.
    - detuning can be done with lumped components or by changing the lengths of the elements
  - In my opinion this is closer to log-periodic than phased array

Applications

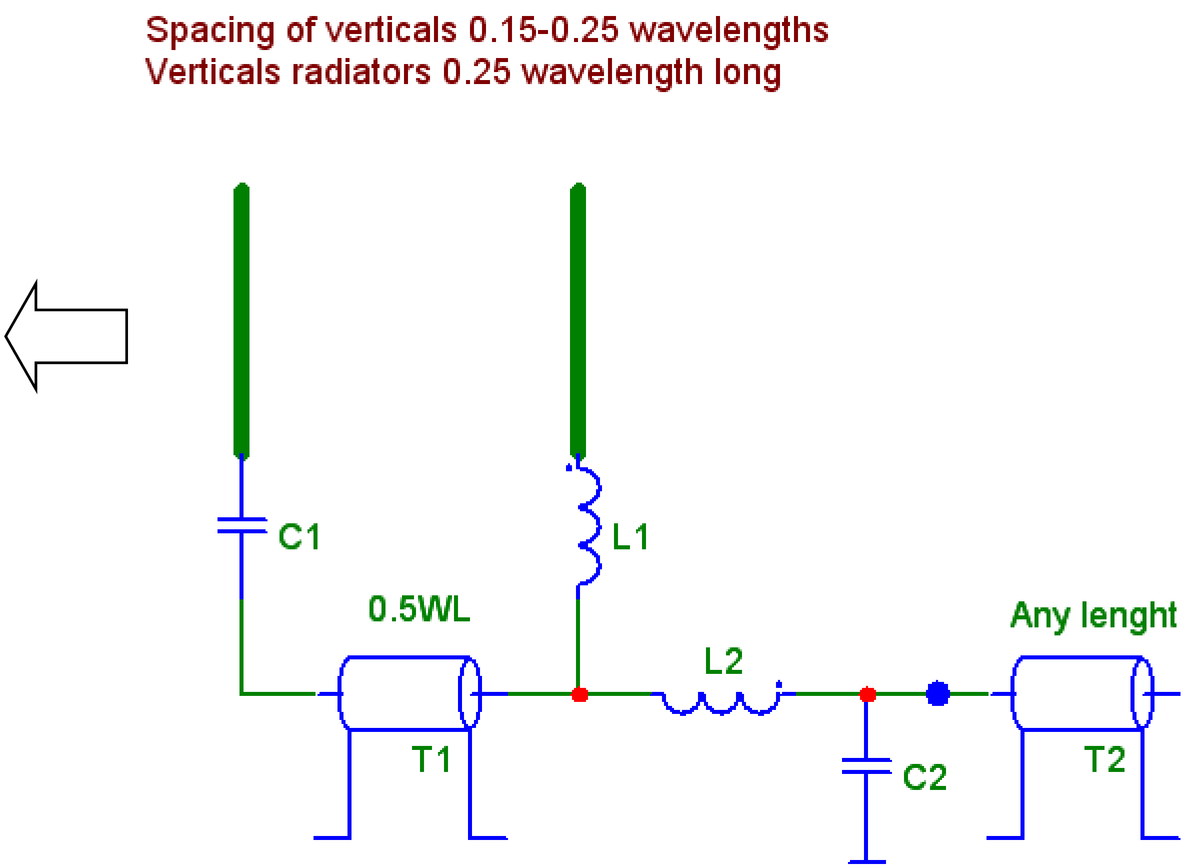
- In amateur radio
  - High performance HF monoband antenna from 80m to 10m
    - On low bands, 80m-30m, two elements may be the maximum one can have
    - When instant 180 degree direction change is an advantage
      - contest station etc.
  - Two element vertical array without “phasing box”
    - By using lumped components for detuning, direction switching is possible
  - Multiband antenna for QRP
    - Needs quite complex switching however.

Examples of low band antennas

Two element vertical



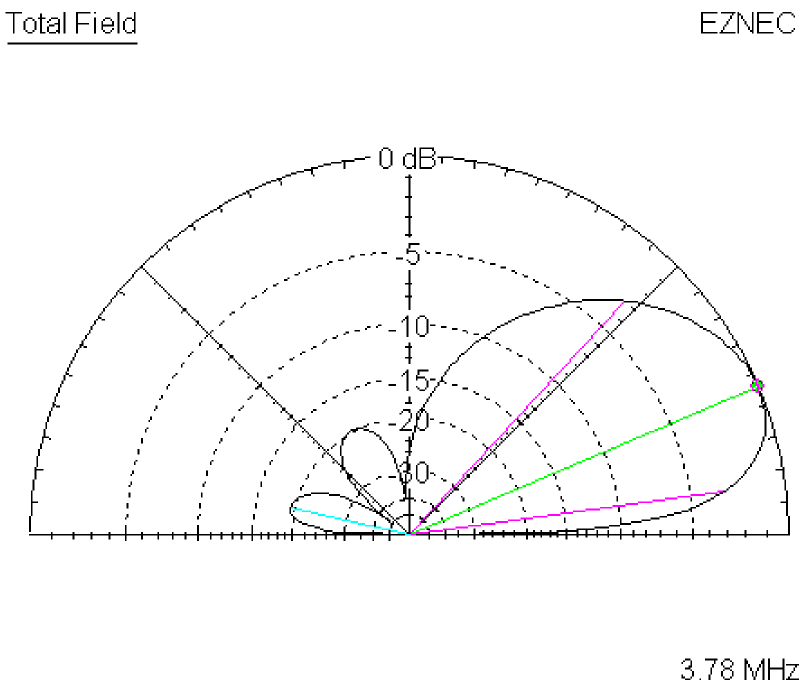
Two element vertical



Opposite voltage fed array by OH1TV

Two verticals for 80m SSB

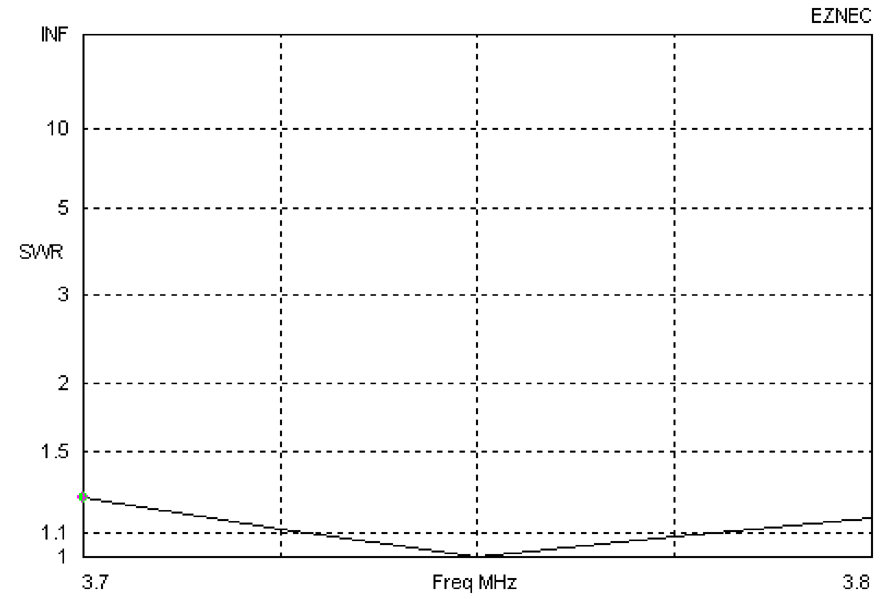
20m spacing, 104 degrees



Elevation Plot
Azimuth Angle 0.0 deg.
Outer Ring 3.79 dBi

Cursor Elev 23.0 deg.
Gain 3.79 dBi
0.0 dBmax

Slice Max Gain 3.79 dBi @ Elev Angle = 23.0 deg.
Beamwidth 39.5 deg.; -3dB @ 7.8, 47.3 deg.
Sidelobe Gain -15.66 dBi @ Elev Angle = 167.0 deg.
Front/Sidelobe 19.44 dB



Freq 3.7 MHz
SWR **1.26**
Z 41.68 at 7.96 deg.
= 41.28 + j 5.769 ohms
Refl Coeff 0.1143 at 142.89 deg.
= -0.09116 + j 0.06896
Ret Loss 18.8 dB

Source # 1
Z0 50 ohms

L1=2.2uH

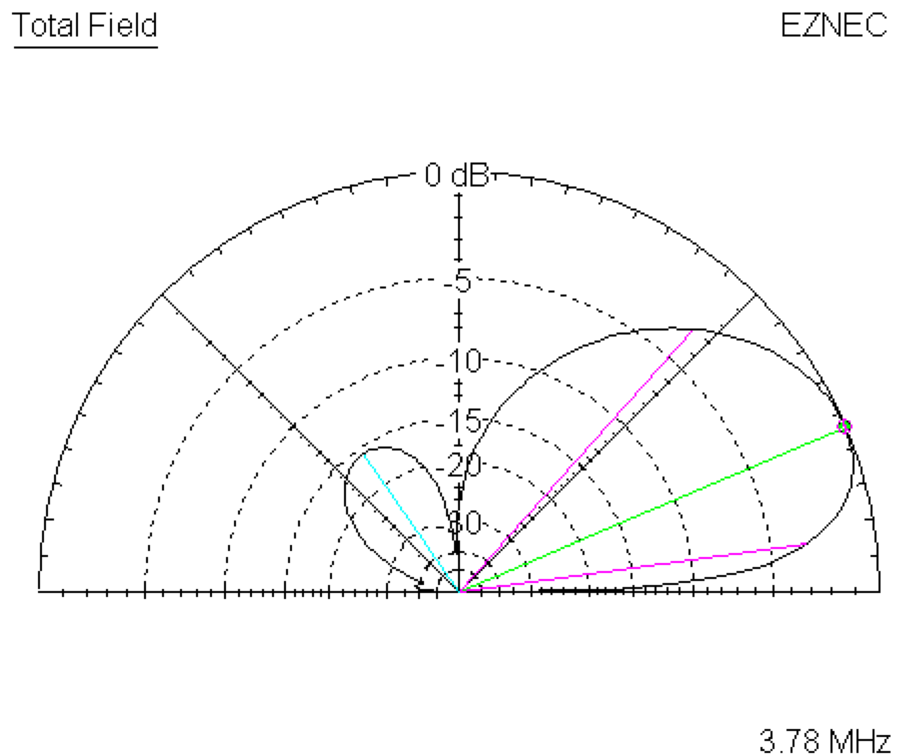
C1=1400pF

Two verticals for 80m SSB

20m spacing, 90 degrees

L1=2.7uH

C1=1050pF

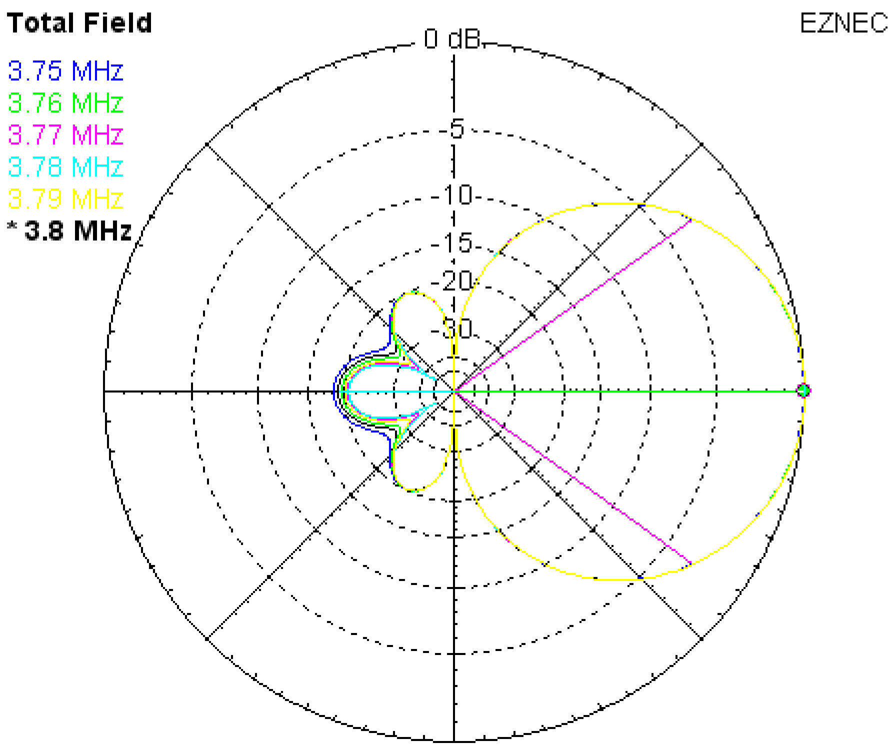


Elevation Plot			Cursor Elev	23.0 deg.
Azimuth Angle	0.0 deg.		Gain	3.41 dBi
Outer Ring	3.41 dBi			0.0 dBmax

Slice Max Gain	3.41 dBi @ Elev Angle = 23.0 deg.
Beamwidth	40.2 deg.; -3dB @ 7.9, 48.1 deg.
Sidelobe Gain	-12.32 dBi @ Elev Angle = 125.0 deg.
Front/Sidelobe	15.73 dB

80m SSB, horizontal elements 30m long

boom 12m, optimized for free space



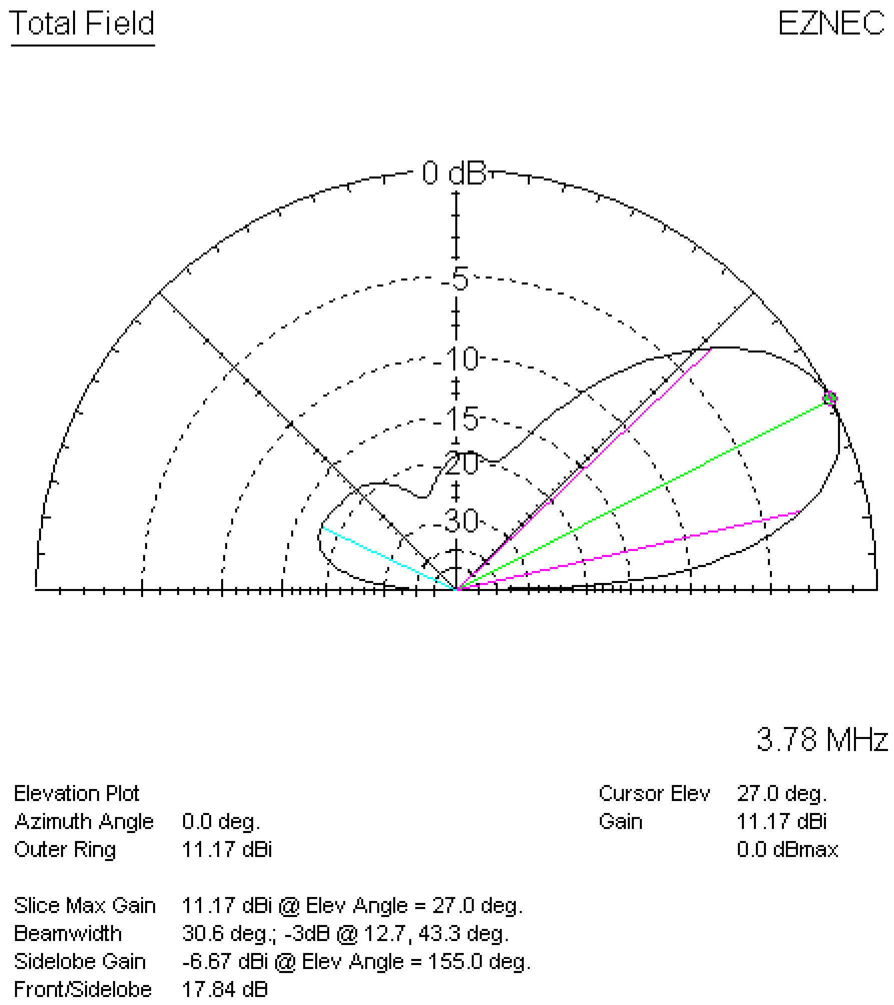
Azimuth Plot
Elevation Angle 0.0 deg.
Outer Ring 6.26 dBi

Cursor Az 0.0 deg.
Gain 6.26 dBi
0.0 dBmax

Slice Max Gain 6.26 dBi @ Az Angle = 0.0 deg.
Front/Back 18.93 dB
Beamwidth 72.0 deg.; -3dB @ 324.0, 36.0 deg.
Sidelobe Gain -12.68 dBi @ Az Angle = 180.0 deg.
Front/Sidelobe 18.93 dB

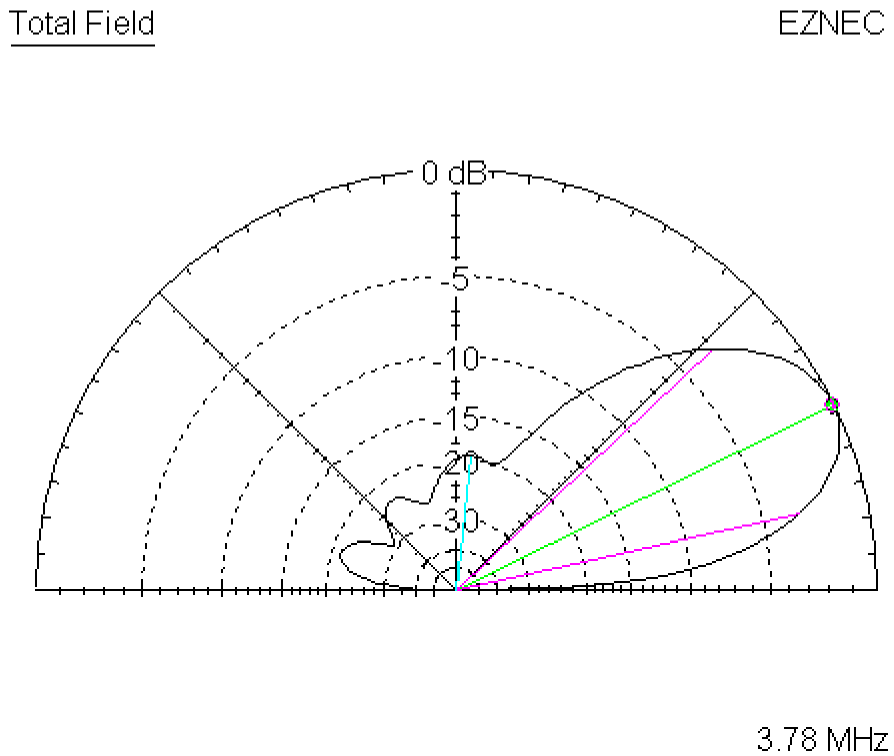
80m SSB, elements 30m long

boom 12m, antenna height 40m, optimized for free space



80m SSB, elements 30m long

boom 12m, antenna optimized for 40m height

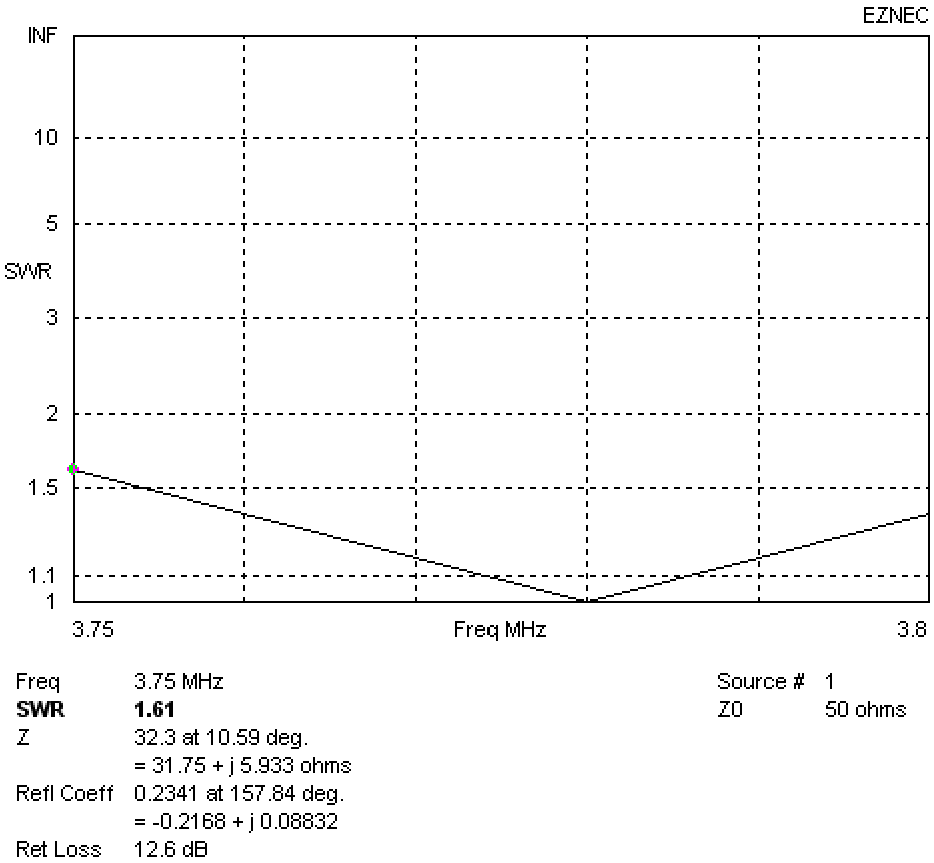


Elevation Plot			Cursor Elev	26.0 deg.
Azimuth Angle	0.0 deg.		Gain	11.32 dBi
Outer Ring	11.32 dBi			0.0 dBmax

Slice Max Gain	11.32 dBi @ Elev Angle = 26.0 deg.
Beamwidth	30.5 deg.; -3dB @ 12.6, 43.1 deg.
Sidelobe Gain	-8.19 dBi @ Elev Angle = 84.0 deg.
Front/Sidelobe	19.51 dB

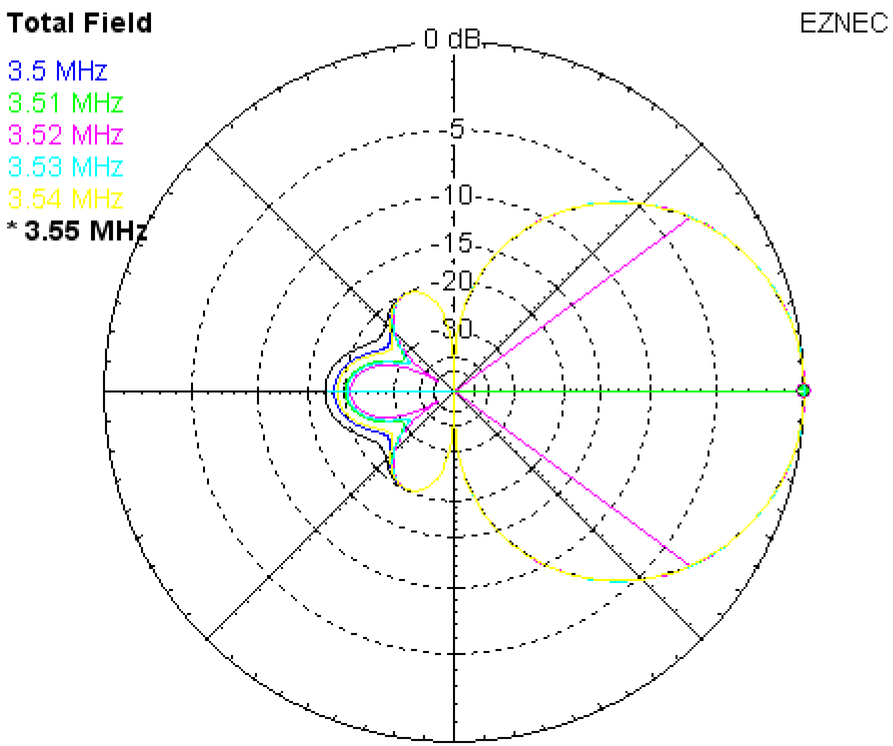
80m SSB, elements 30m long

boom 12m



80m CW, elements 30m long

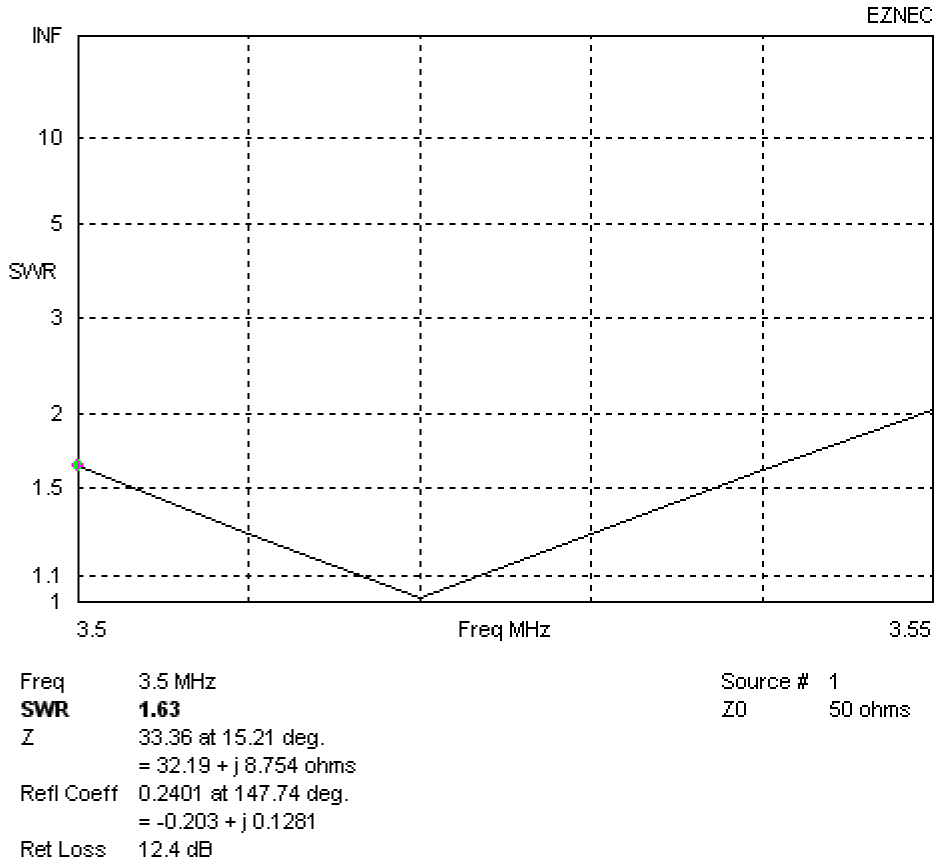
boom 12m



Azimuth Plot		Cursor Az	0.0 deg.
Elevation Angle	0.0 deg.	Gain	6.19 dBi
Outer Ring	6.22 dBi		0.0 dBmax

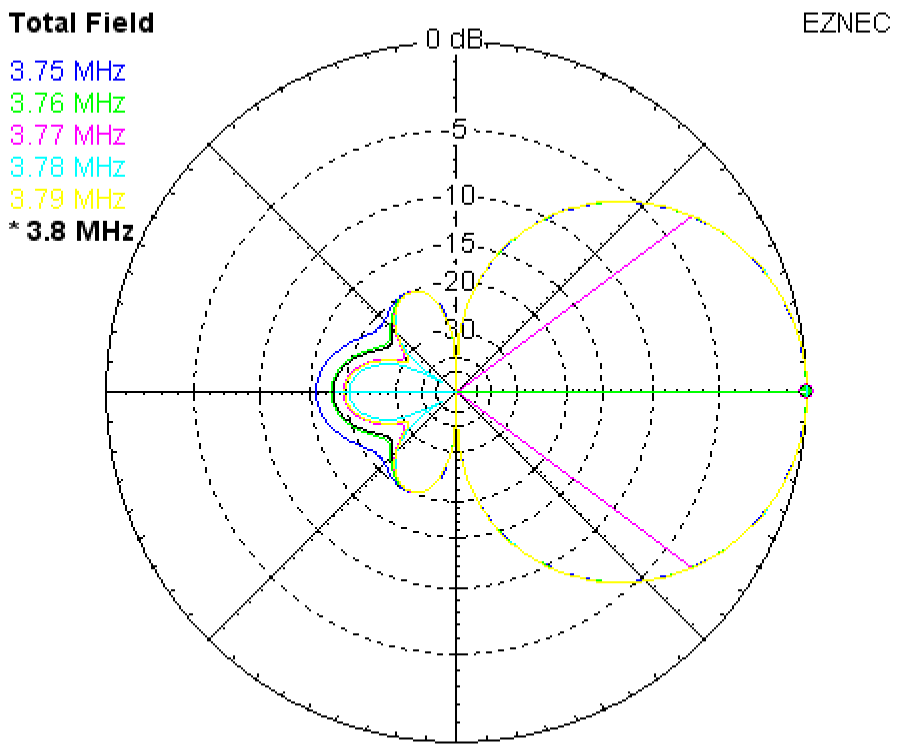
Slice Max Gain 6.19 dBi @ Az Angle = 0.0 deg.
Front/Back 17.12 dB
Beamwidth 72.4 deg.; -3dB @ 323.8, 36.2 deg.
Sidelobe Gain -10.93 dBi @ Az Angle = 180.0 deg.
Front/Sidelobe 17.12 dB

80m CW, elements 30m long
boom 12m



80m SSB, 26m long elements

boom 12m, optimized for free space



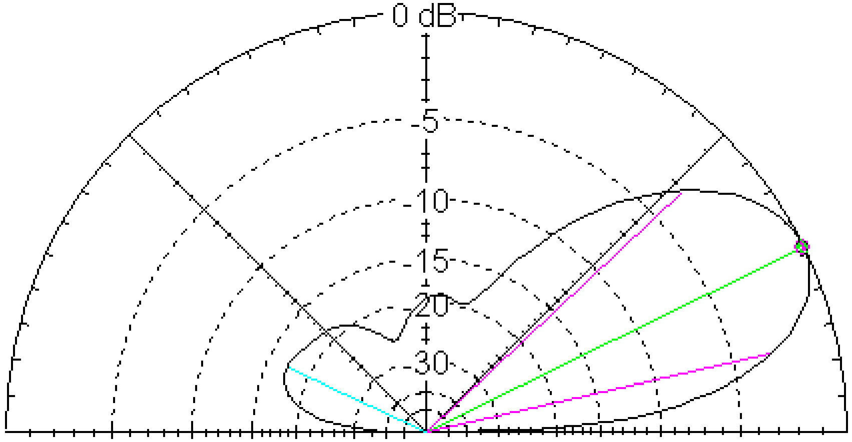
Azimuth Plot
Elevation Angle 0.0 deg.
Outer Ring 6.19 dBi

Cursor Az 0.0 deg.
Gain 6.18 dBi
0.0 dBmax

Slice Max Gain 6.18 dBi @ Az Angle = 0.0 deg.
Front/Back 17.97 dB
Beamwidth 73.2 deg.; -3dB @ 323.4, 36.6 deg.
Sidelobe Gain -11.79 dBi @ Az Angle = 180.0 deg.
Front/Sidelobe 17.97 dB

80m SSB, 26m long elements

boom 12m, 40m high, optimized for free space

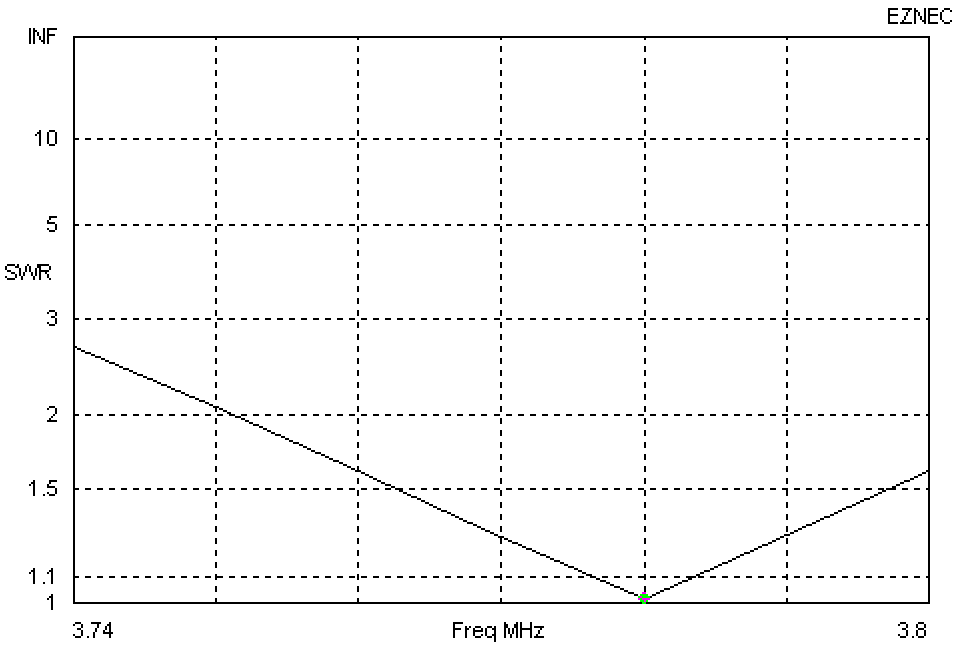


Elevation Plot		Cursor Elev	26.0 deg.
Azimuth Angle	0.0 deg.	Gain	11.09 dBi
Outer Ring	11.09 dBi		0.0 dBmax

Slice Max Gain	11.09 dBi @ Elev Angle = 26.0 deg.
Beamwidth	30.5 deg.; -3dB @ 12.7, 43.2 deg.
Sidelobe Gain	-6.21 dBi @ Elev Angle = 155.0 deg.
Front/Sidelobe	17.3 dB

80m SSB, 26m long elements

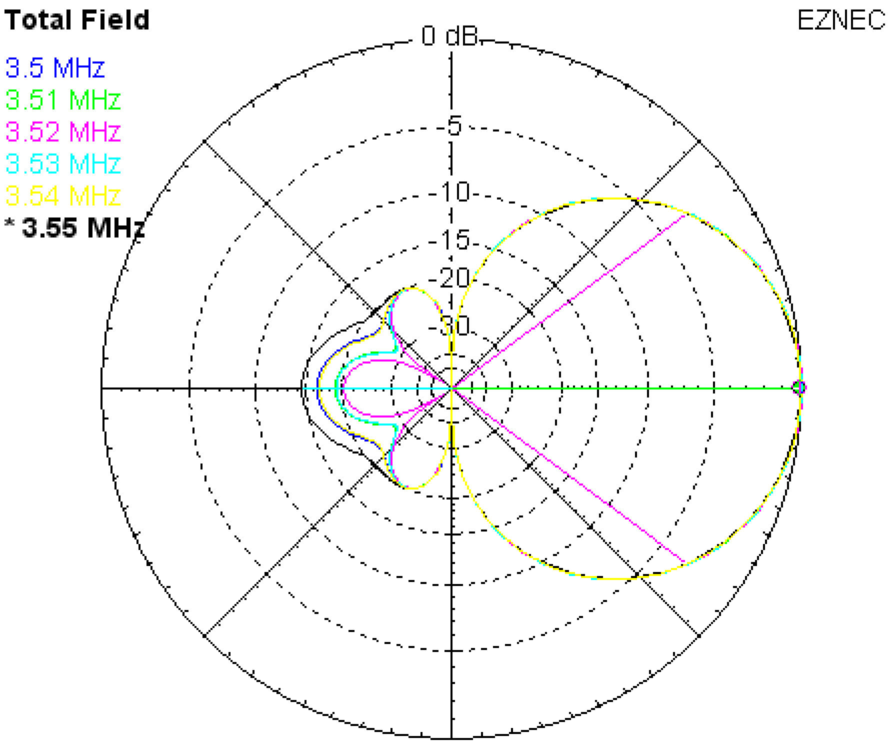
boom 12m



Freq	3.78 MHz	Source #	1
SWR	**1.013**	Z0	50 ohms
Z	49.76 at -0.69 deg.		
	= 49.76 - j 0.5995 ohms		
Refl Coeff	0.006473 at -111.45 deg.		
	= -0.002367 - j 0.006024		
Ret Loss	43.8 dB		

80m CW, 26m long elements

12m boom, free space

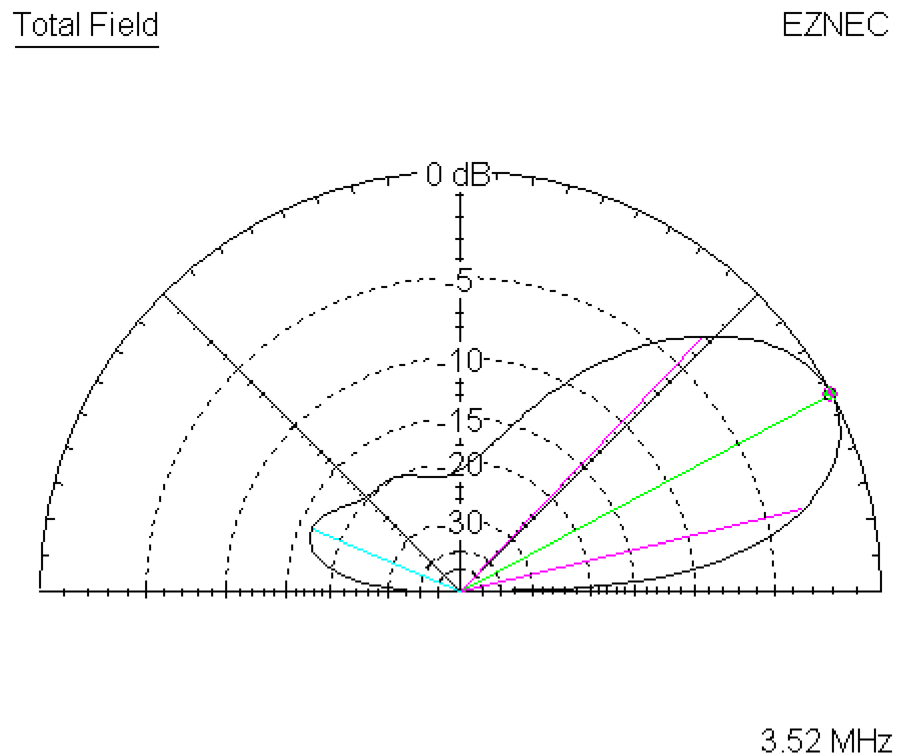


Azimuth Plot		Cursor Az	0.0 deg.
Elevation Angle	0.0 deg.	Gain	6.08 dBi
Outer Ring	6.16 dBi		0.0 dBmax

Slice Max Gain	6.08 dBi @ Az Angle = 0.0 deg.
Front/Back	14.48 dB
Beamwidth	73.2 deg.; -3dB @ 323.4, 36.6 deg.
Sidelobe Gain	-8.4 dBi @ Az Angle = 180.0 deg.
Front/Sidelobe	14.48 dB

80m CW, 26m long elements

12m boom, 40m high, optimized for free space



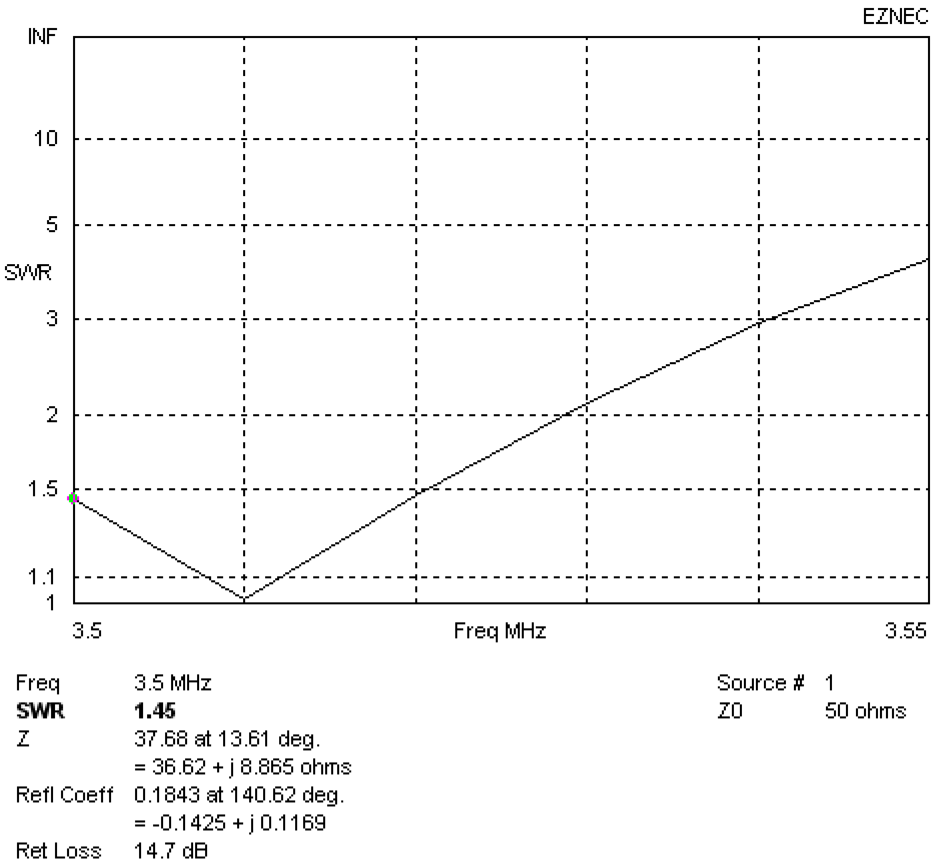
Elevation Plot
Azimuth Angle 0.0 deg.
Outer Ring 10.73 dBi

Cursor Elev 28.0 deg.
Gain 10.73 dBi
0.0 dBmax

Slice Max Gain 10.73 dBi @ Elev Angle = 28.0 deg.
Beamwidth 33.0 deg.; -3dB @ 13.4, 46.4 deg.
Sidelobe Gain -5.75 dBi @ Elev Angle = 157.0 deg.
Front/Sidelobe 16.48 dB

80m CW, 26m long elements

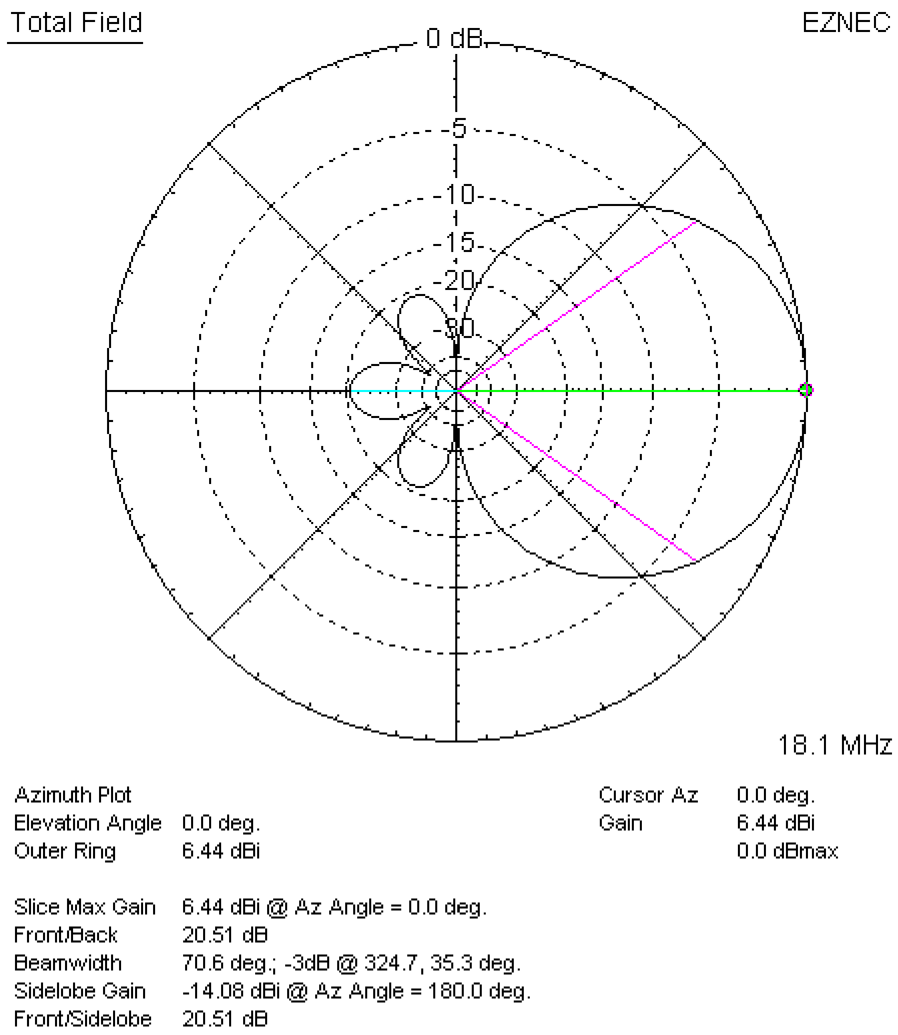
12m boom, free space



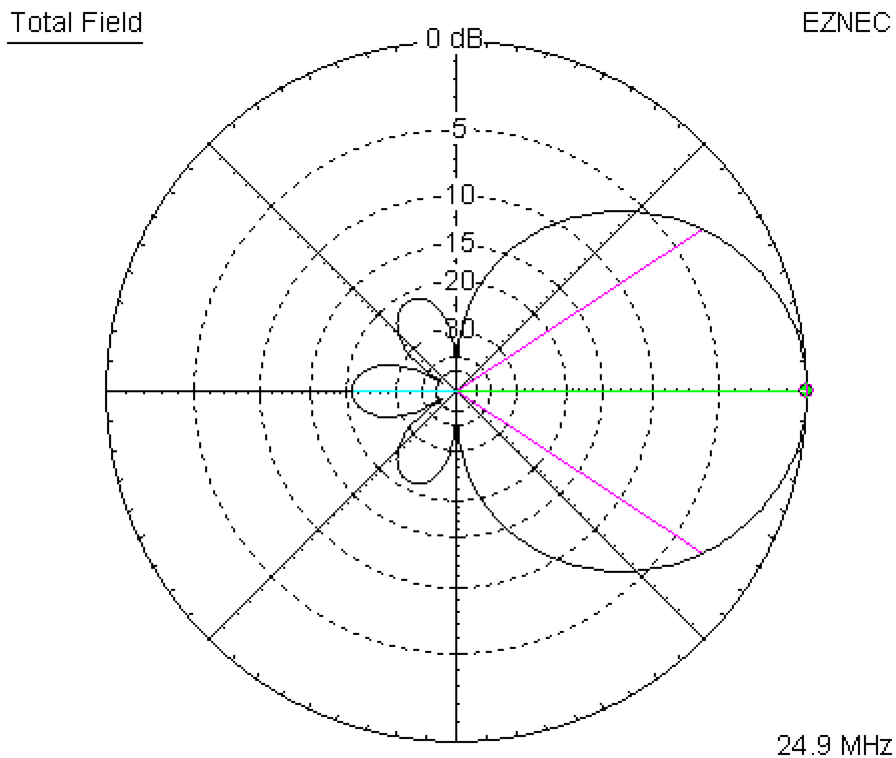
Multibanding

- How to do
  - For each band ½ wavelength inter-element cable is needed for voltage inversion and voltage forcing
  - Two serial capacitors in the center of both elements are needed to shorten the electrical length of the elements. Coils can be used to lengthen the elements
    - As an example antenna originally made for 21MHz can be tuned this way to 18, 25 and 28 MHz
  - Gain patter do not change, forward gain remains the same.
  - When tuning up in frequency, antenna feedpoint impedance increases and opposite happens when tuning down.
    - L-match can be used to reach 50 ohm.
  - When tuning up, voltages increase and reliability of the switches becomes a challenge.
    - At least for QRP this can be good multiband antenna.

15m antenna tuned to 17m



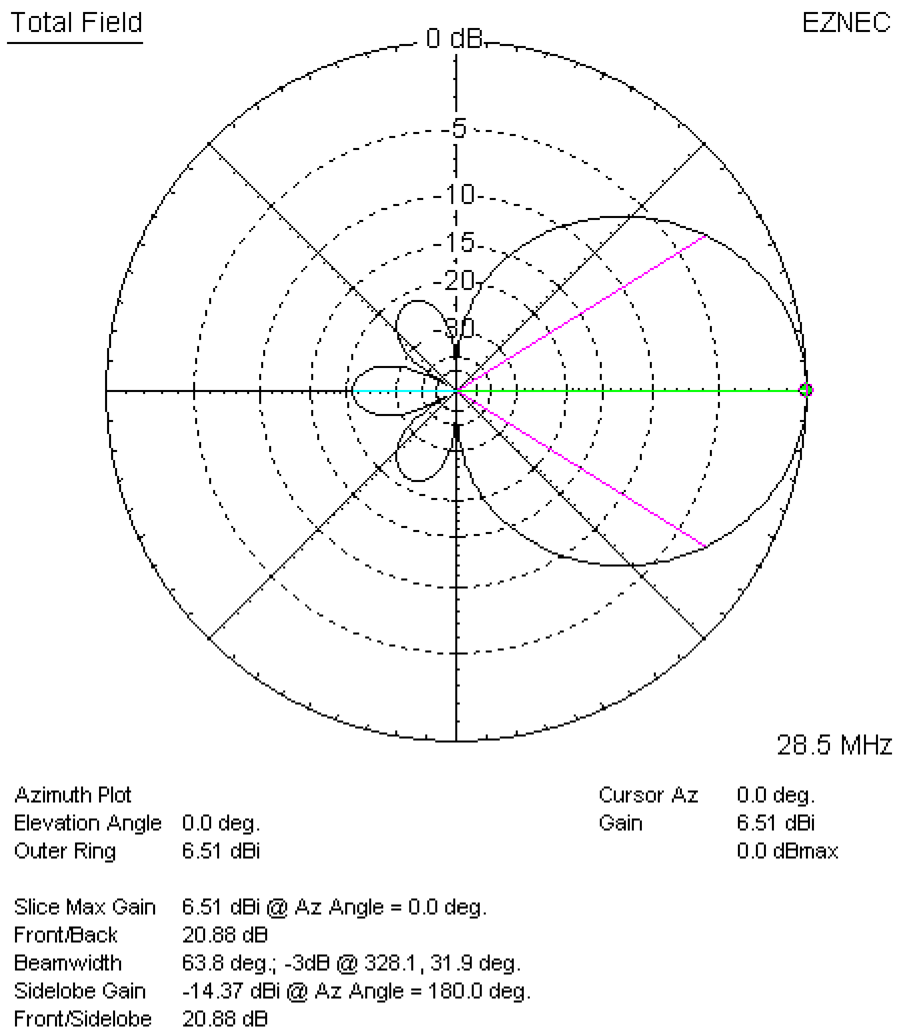
15m antenna tuned to 12m



Azimuth Plot		Cursor Az	0.0 deg.
Elevation Angle	0.0 deg.	Gain	6.51 dBi
Outer Ring	6.51 dBi		0.0 dBmax

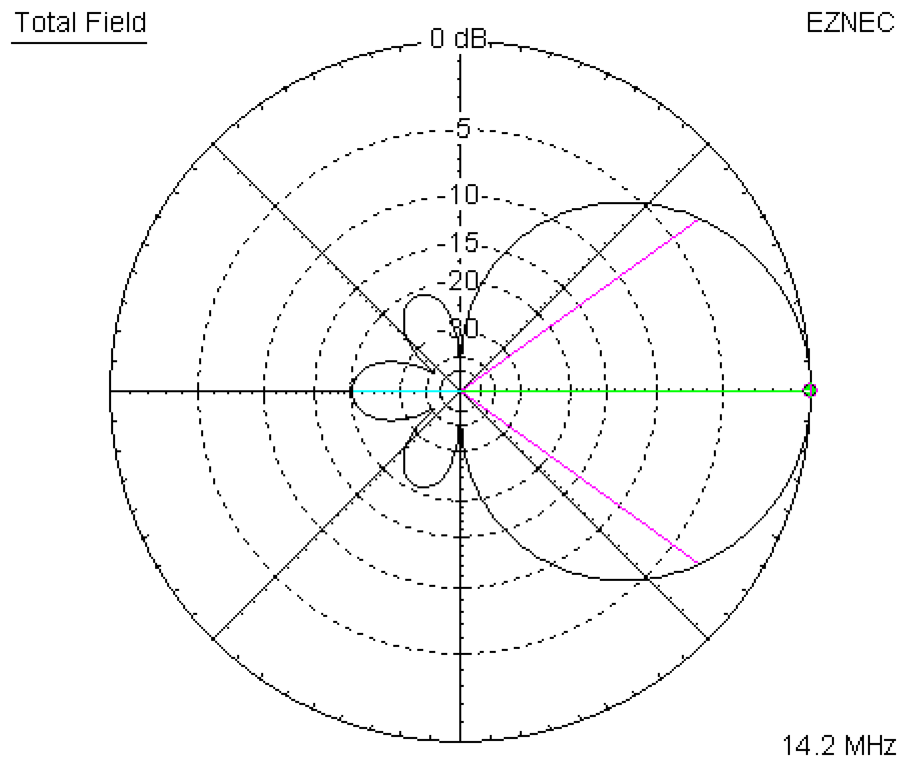
Slice Max Gain	6.51 dBi @ Az Angle = 0.0 deg.
Front/Back	20.77 dB
Beamwidth	66.6 deg.; -3dB @ 326.7, 33.3 deg.
Sidelobe Gain	-14.26 dBi @ Az Angle = 180.0 deg.
Front/Sidelobe	20.77 dB

15m antenna tuned to 10m



15m antenna tuned to 20m

SWR<1.5 -bandwidth is only 50kHz, not usable



Azimuth Plot			Cursor Az	0.0 deg.
Elevation Angle	0.0 deg.		Gain	6.16 dBi
Outer Ring	6.16 dBi			0.0 dBmax

Slice Max Gain	6.16 dBi @ Az Angle = 0.0 deg.
Front/Back	20.21 dB
Beamwidth	72.0 deg.; -3dB @ 324.0, 36.0 deg.
Sidelobe Gain	-14.05 dBi @ Az Angle = 180.0 deg.
Front/Sidelobe	20.21 dB