



Antenna simulations

Part 1

Pekka Ketonen, OH1TV

Outline

Part 1

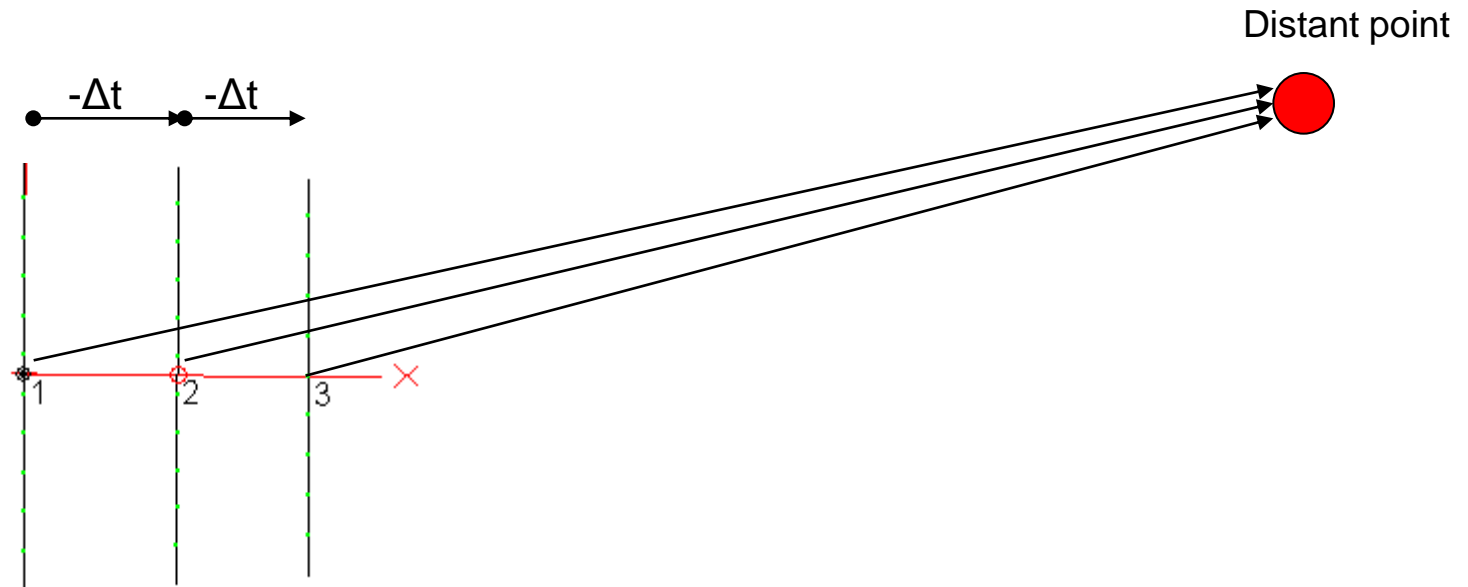
- Some principles in antenna design
 - typical steps in design process
- Opposite Voltage Feed
 - 2 phased verticals on 80m
 - 2 over 2 on 40m
 - Quad improved

Part 2

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

Some principles in antenna design, typical steps in design process

Fields are superimposed in the distant point

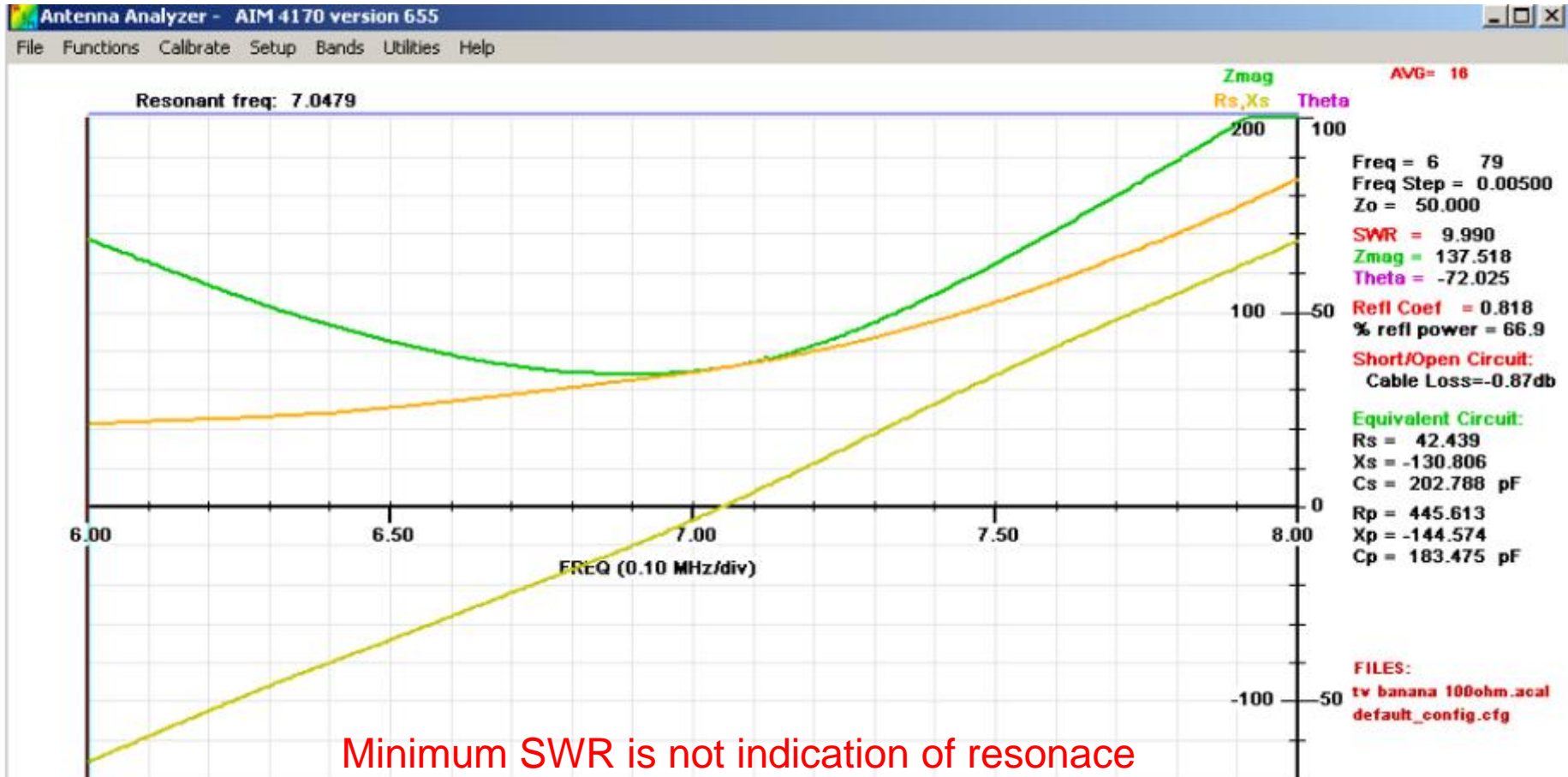


- Distance to dx point is slightly different from each element
- By delaying the driving signals towards the front element we get signals into phase in distant point

Some basics about antennas

- Radiation pattern is defined by
 - antenna geometry
 - current distribution
 - reflecting environment (often ground or water)
- One shall recognize that
 - It doesn't matter how the currents are achieved
 - current forcing by phasing network, or
 - auto feed by mutual coupling, parasitic element
 - Elements need not to be resonant, any impedance is good
 - It is always possible to make a matching network
 - In parasitic Yagi the tuning of driven element has very little influence to radiation pattern.

Element is in resonance when
feedpoint impedance is pure resistive, reactance = 0



Antenna efficiency

- Power can be lost in
 - Radiating wires (copper, alumina, steel)
 - Loading components (coils, capacitor)
 - Cables
 - Phasing and matching networks
 - Reflecting surface (ground, water)
 - Vertical polarization: losses increase when angle of radiation decreases
 - Reflector resistances parallel
 - **Antenna environment is the key**
 - Horizontal : losses increase when angle of radiation increases
 - Reflector resistances in series
 - Power lost $P = I^2 * R$, lower impedance level > higher losses

Steps to design antennas

1. Target specification, goal
2. Radiation pattern design: gain, sidelobe attenuation, F/B
 - antenna geometry, including installation location (HF-antenna is a system)
 - current distribution by current forcing
 - this is a kind of ideal case
3. How to achieve wanted current distributions
 - in case of parasitic array this goes parallel with radiation pattern design
 - phasing method and network design
4. Matching to feedline (50ohm)
 - good antenna may have strange input impedance
5. Methods to align, test and verify

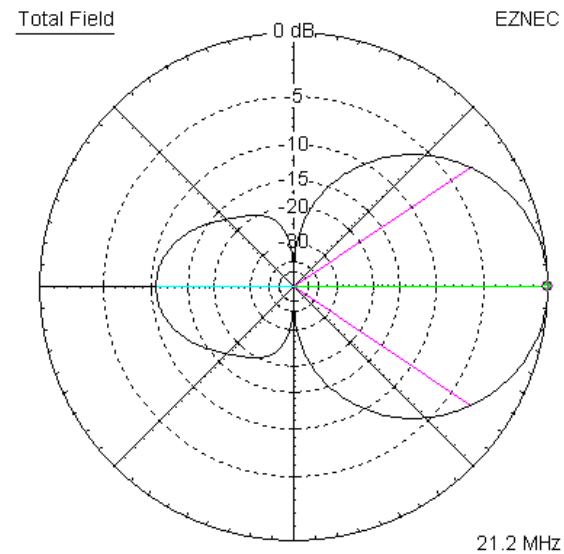
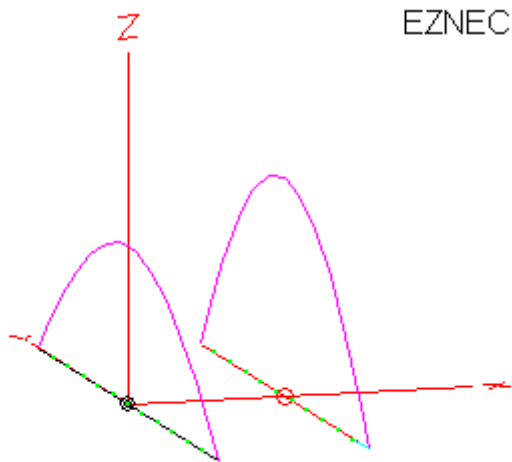
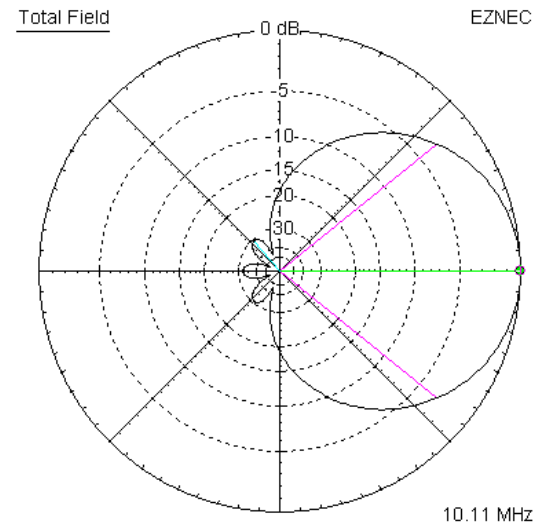
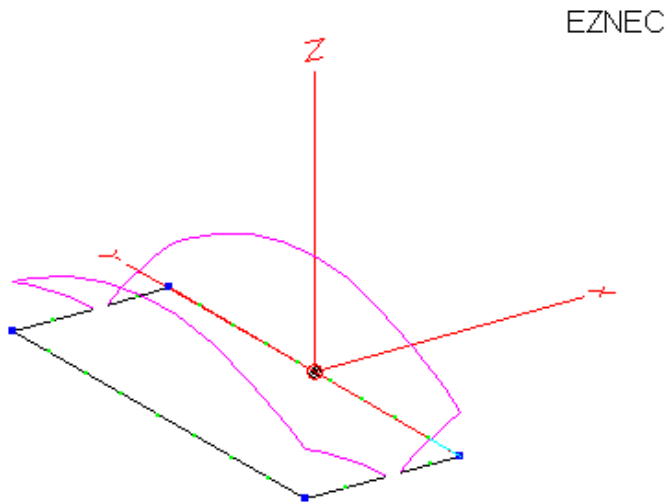
In practice this work is highly iterative

2.1. Radiation pattern

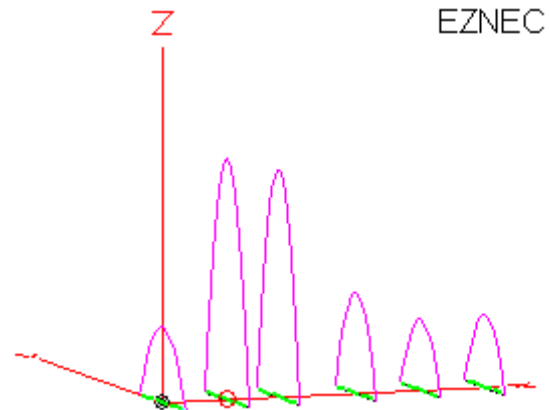
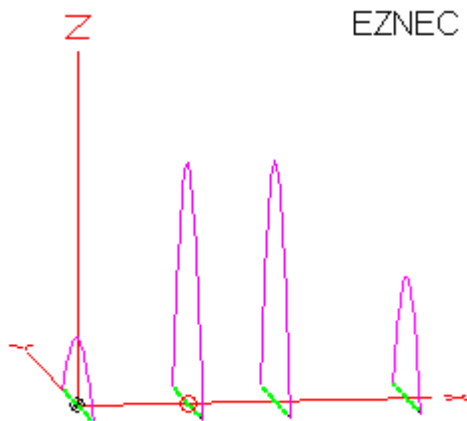
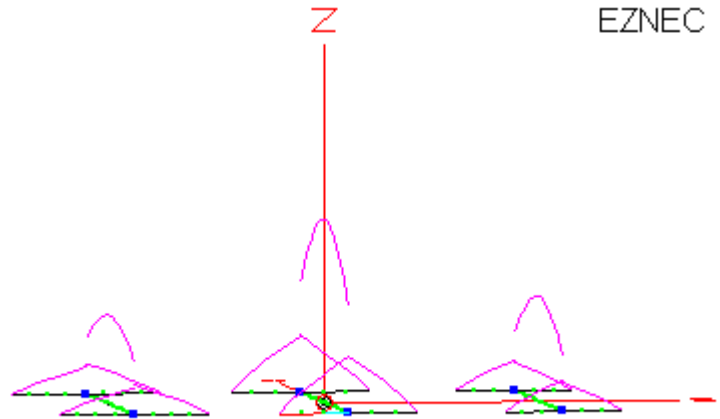
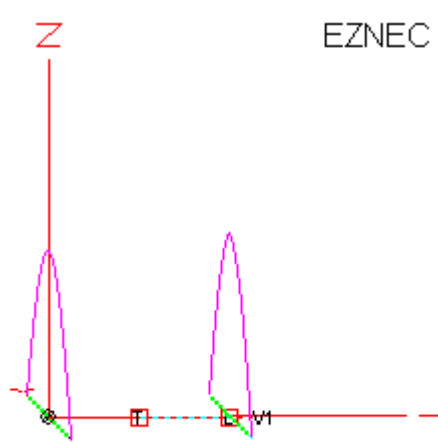
Depends on

- Element locations, positions, geometry
 - Boom length
- Element current relations, amplitude and phase
- Element size and shape
 - 0.25-1.0 wave length or so
 - straight, square, round, V-shaped, U-shaped, and so on
 - non-tapered, tapered, thick, thin
- Amplitude distribution of current in element
 - Sinus, triangle, constant, combination of those
 - Phase normally remains constant over each $\lambda/2$ section
- Losses
 - Radiator and other component conductivity
 - Material constants

2.2. Straight element is not always the best



3.0.Current distribution between elements



3.1. Current distribution between elements

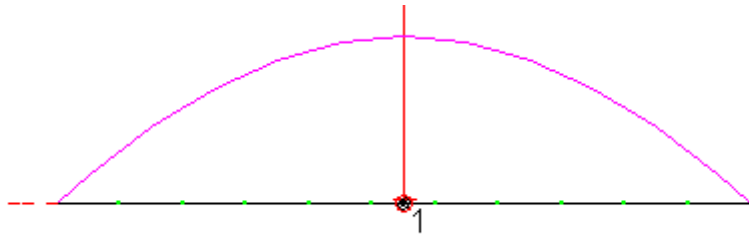
How?

1. By current forcing, phased array
 1. $\frac{1}{4} \lambda$ cable to each element from phasing box
 2. Voltage relations in the box lead to similar current relations in the elements
 1. Element impedance has no influence to current
2. By mutual coupling, parasitic array
 1. With element detuning and distance to other elements we can control the element current amplitude and phase
 2. In multielement array these interactions are complex and it is difficult manage
 3. Certain “standard designs” exist
3. Combination of mutual coupling and voltage bias
 1. “Opposite voltage feed” by OH1TV
4. Combination of those above

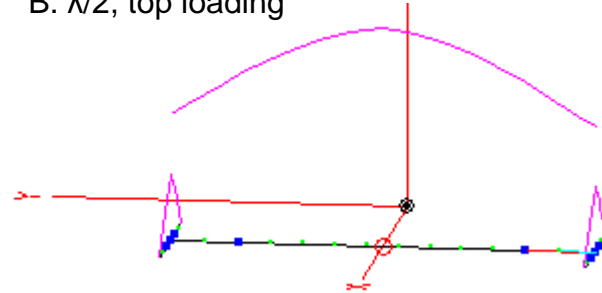
3.2. Current distribution of an antenna element

How?

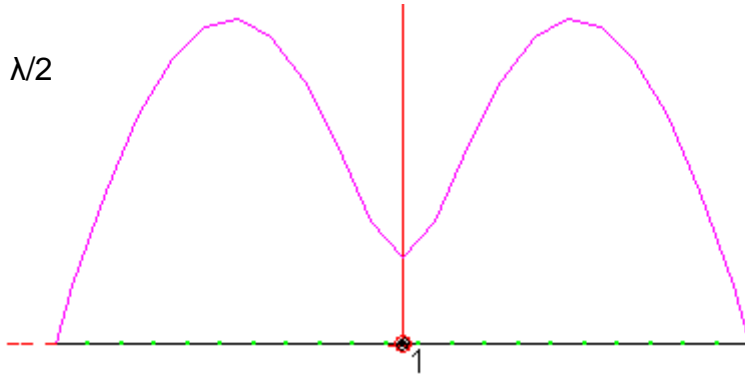
A. $\lambda/2$



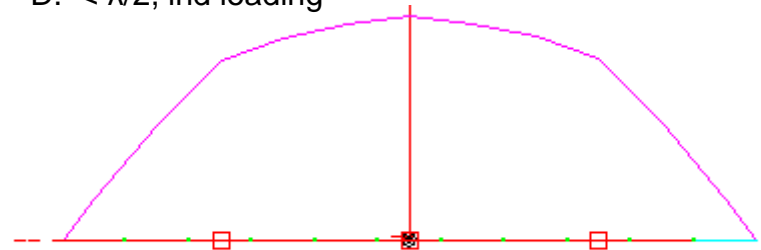
B. $\lambda/2$, top loading



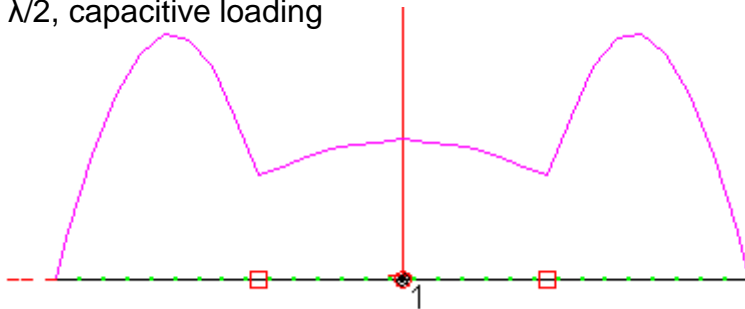
C. $> \lambda/2$



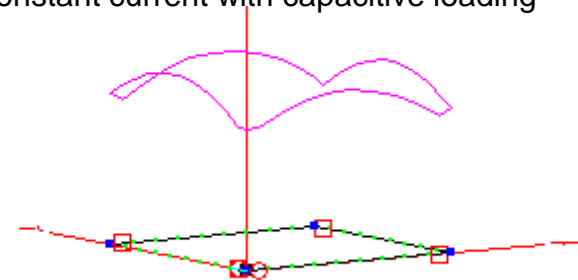
D. $< \lambda/2$, ind loading



E. $< \lambda/2$, capacitive loading



F. constant current with capacitive loading



4.1 Matching to feedline

- All power is transferred to antenna, when antenna impedance equals to feedline impedance
 - In practice cables are 50 ohm resistive
- The natural feedpoint impedance of antennas only seldom is 50 ohm
 - In most cases a matching unit is needed
- Matching unit has no effect to antenna radiation pattern

4.2 Matching unit can be

1. Wideband transformer

- Antenna impedance needs to be resistive
- Doesn't remove reactive part

2. $\frac{1}{4}$ wavelength cable, $Z_0 = \sqrt{Z_1 \times Z_2}$

- May be difficult to find suitable cable

3. Reactive components can be removed to changed

- Serial capacitor to negative direction
- Serial inductance to positive direction

4. L-match

- Both reactive component removal and transformation of resistive part
- Lumped components: Coils and capacitors
- We can make use of reactive componets in antenna impedance
 - hairpin match, element is made short in order to generate capacitive reactance

5. Methods to align, test and verify

- Modeling with EZNEC and measuring with vector analyzers like AIM4170 or VNA2180 support each other
 - The model gives for each element impedance when in system or alone
 - The impedance can be measured
- Elements can be aligned one by one to their individual specifications
 - In a multi-element array mutual influence between elements is so complex that it is very challenging to do experimental alignment
- Aligning matching unit with by sing AIM is a straight forward procedure
 - Traditional SWR meter is ok for verification but not for alignment
- Verification of current distribution and phases can be done with Vector Network Analyzer like VNA2180.
 - Measured currents can be fed back to the model and radiation pattern plotted based on real current distribution
- To measure absolute gain of an HF- antenna with high accuracy is difficult, relative radiation pattern is much easier.

Opposite Voltage Feed

2 phased verticals on 80m

2 over 2 on 40m

Quad improved

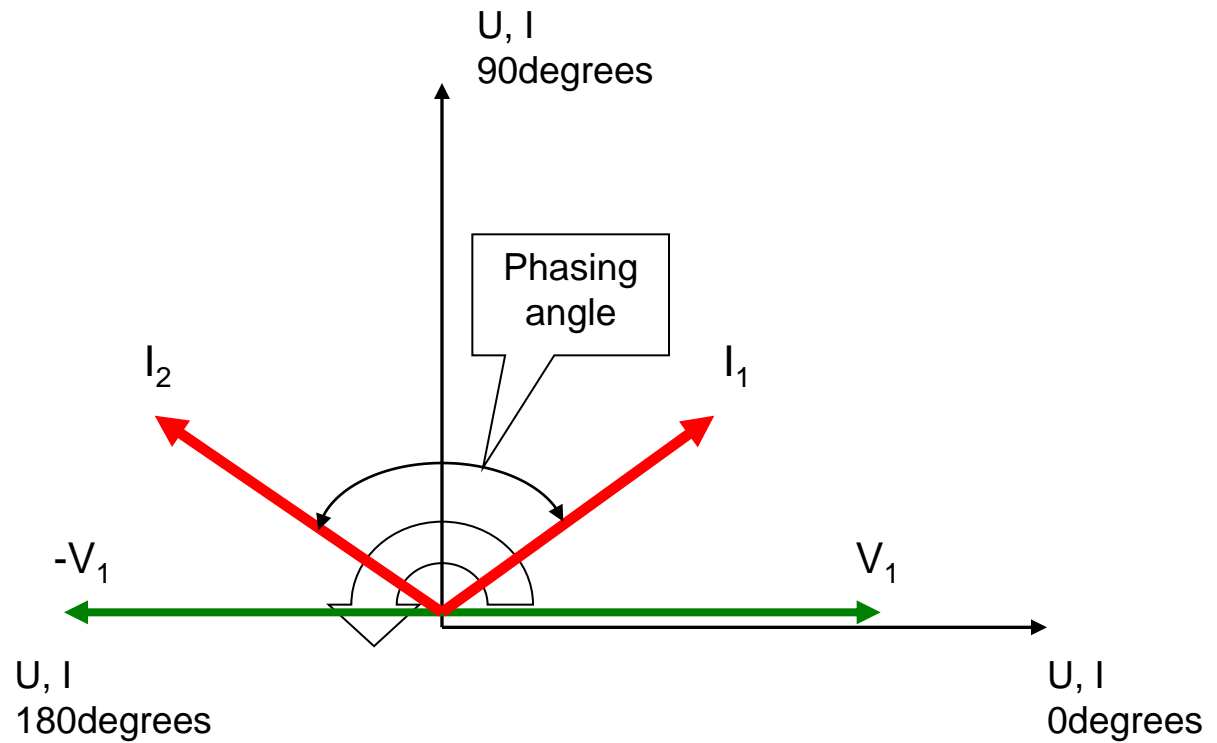
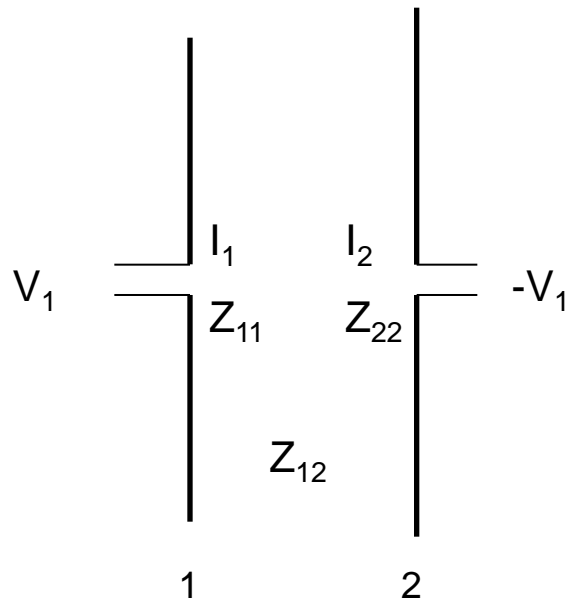
What is Opposite Voltage Feed?

OVF is a method to feed 2-element antennas. It makes possible to adjust current amplitudes and phases so that good radiation pattern can be achieved. The main advantage is insensitivity of radiation pattern to frequency change. The concept is that equal amplitude but opposite phase voltages are brought to the element feedpoints. By selecting proper detuning of the elements and taking into account their mutual impedance, it is possible to reach equal currents and wanted phase difference of the currents. When frequency is changed, both current phases move to the same direction and their difference remains almost constant, making the radiation pattern wideband.

Opposite phase normally is generated with half wavelength cable. It can be achieved also with cable polarity inversion and two cables, each half wavelength long.

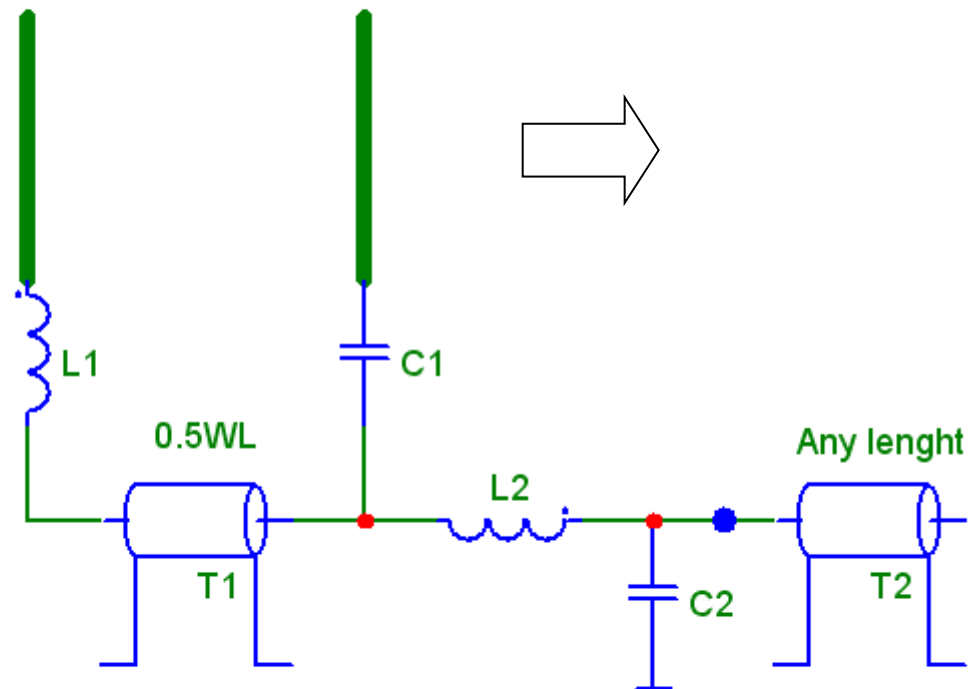
An approximation of phase reversal can be made using very short equal length cables and cable polarity inversion. This method is not perfectly accurate but in most cases adequate.

Voltage and current vectors



Two element vertical

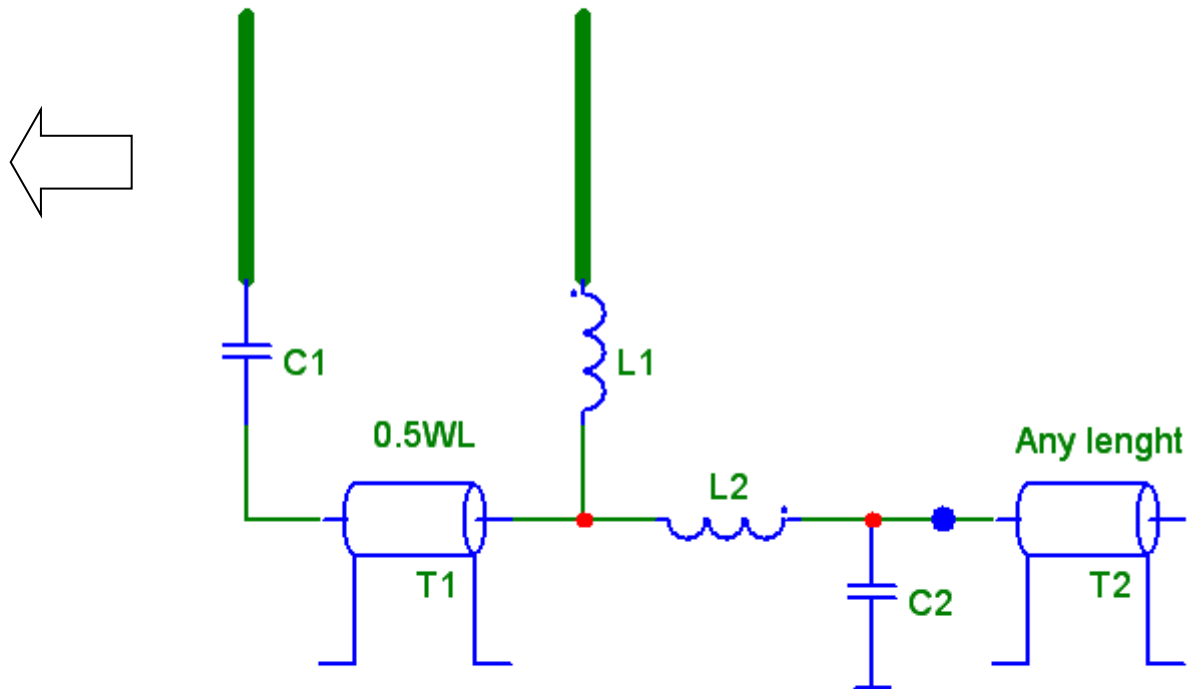
Spacing of verticals 0.15-0.25 wavelengths
Verticals radiators 0.25 wavelength long



Opposite voltage fed array by OH1TV

Two element vertical

Spacing of verticals 0.15-0.25 wavelengths
Verticals radiators 0.25 wavelength long



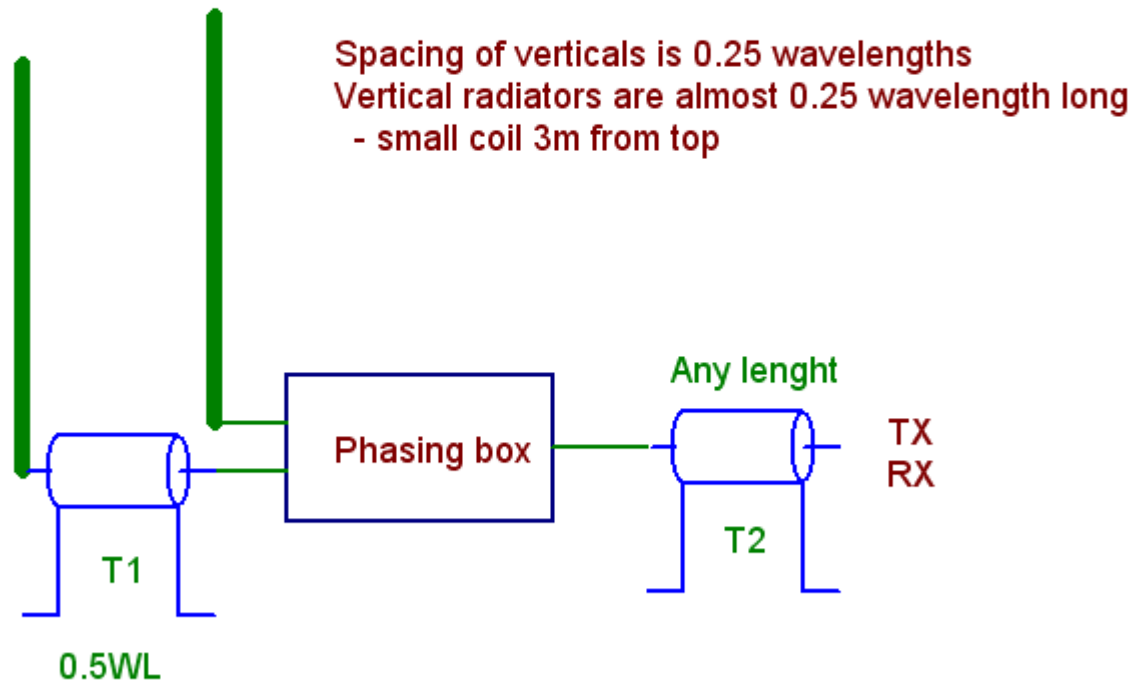
Opposite voltage fed array by OH1TV

2-element vertical array at OH1NM



The concept

Opposite voltages fed array by OH1TV
Case: OH1NM



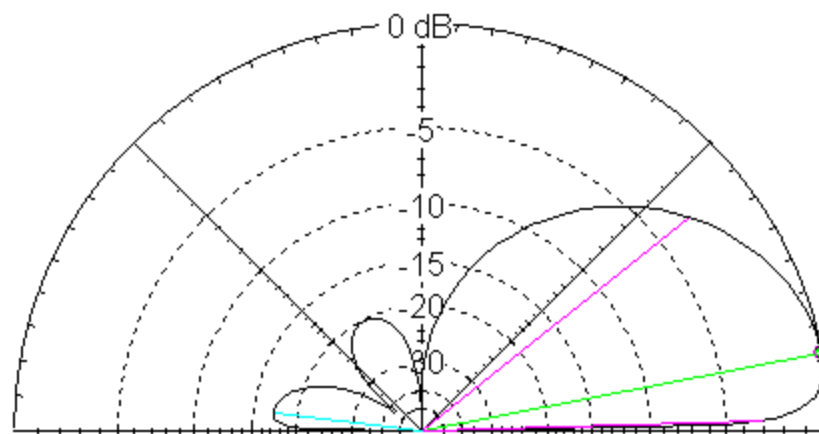


The goal

Total Field

EZNEC

- Seaside QTH
- Elevated radials
- Phasing angle 105 degrees



3.78 MHz

Elevation Plot
Azimuth Angle 0.0 deg.
Outer Ring 7.12 dBi

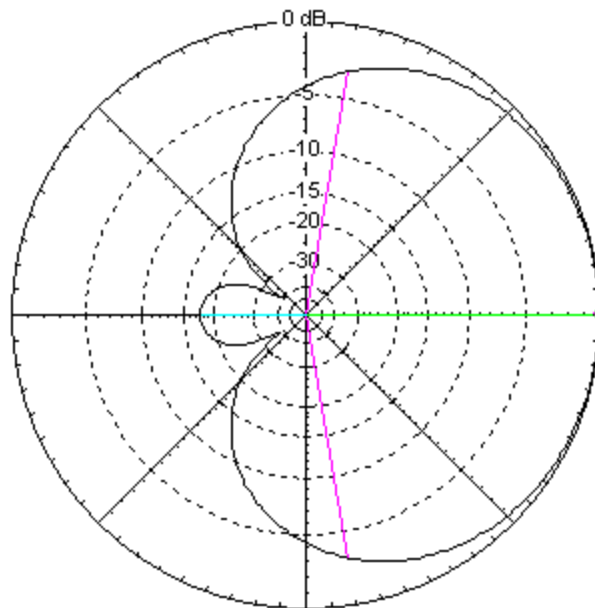
Cursor Elev 11.0 deg.
Gain 7.12 dBi
0.0 dBmax

Slice Max Gain 7.12 dBi @ Elev Angle = 11.0 deg.
Beamwidth 36.7 deg; -3dB @ 1.8, 38.5 deg.
Sidelobe Gain -10.08 dBi @ Elev Angle = 173.0 deg.
Front/Sidelobe 17.19 dB

..the goal

Total Field

EZNEC



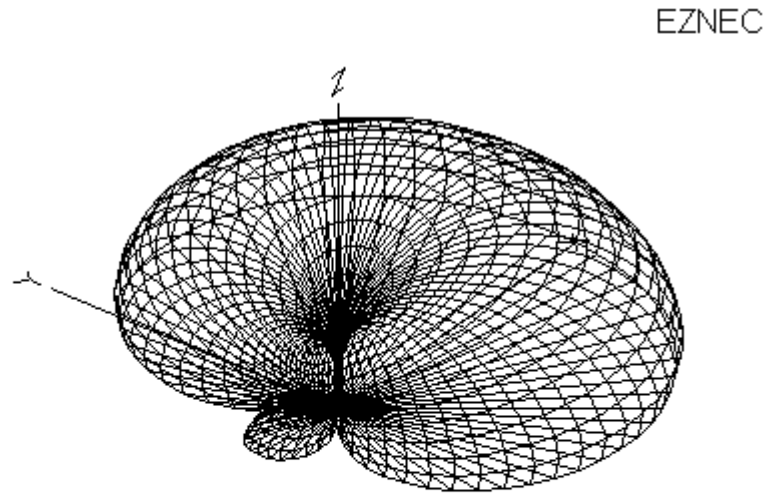
3.78 MHz

Azimuth Plot
Elevation Angle 11.0 deg.
Outer Ring 7.12 dBi

Cursor Az 0.0 deg.
Gain 7.12 dBi
0.0 dBmax

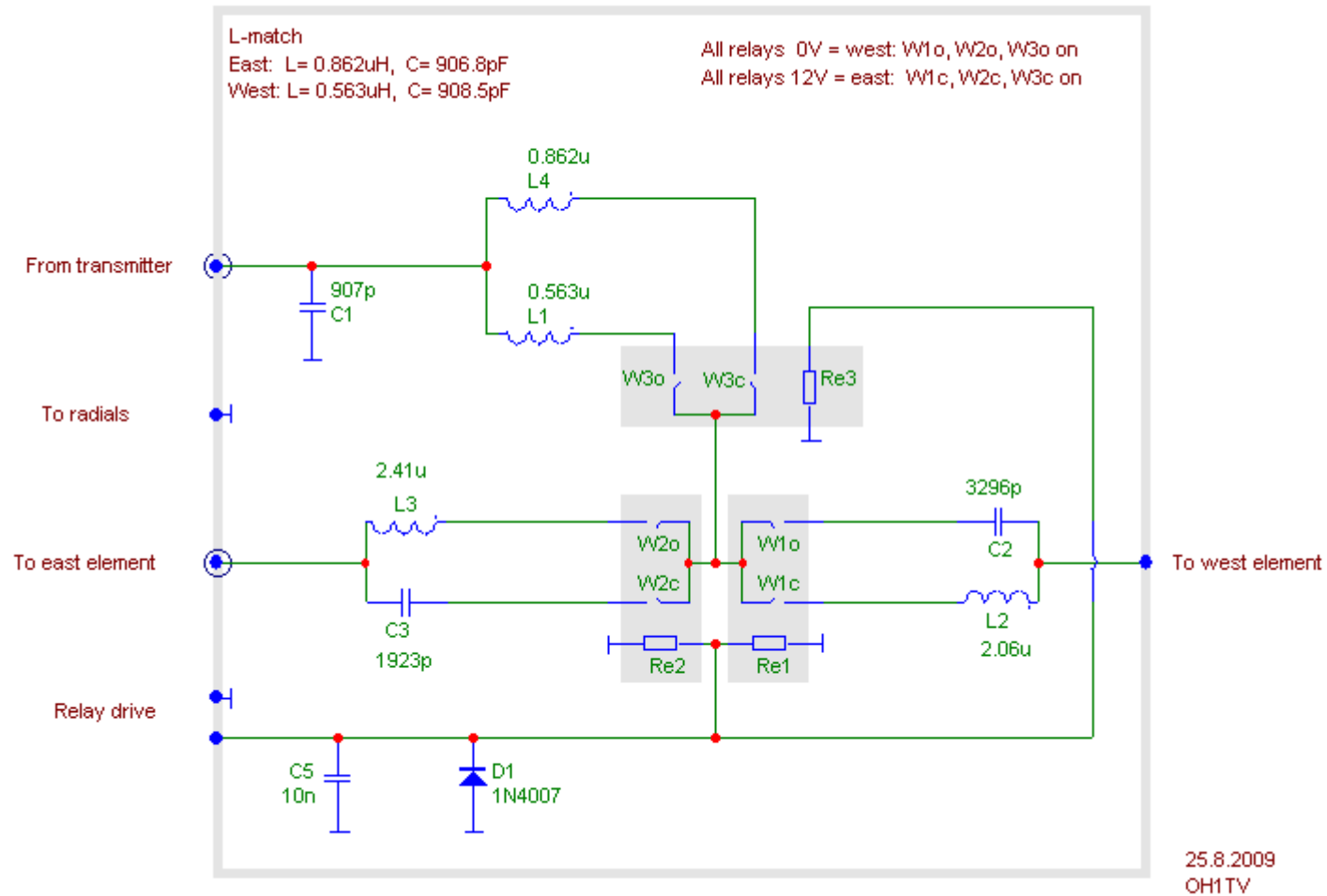
Slice Max Gain 7.12 dBi @ Az Angle = 0.0 deg.
Front/Back 17.54 dB
Beamwidth 160.6 deg.; -3dB @ 279.7, 80.3 deg.
Sidelobe Gain -10.42 dBi @ Az Angle = 180.0 deg.
Front/Sidelobe 17.54 dB

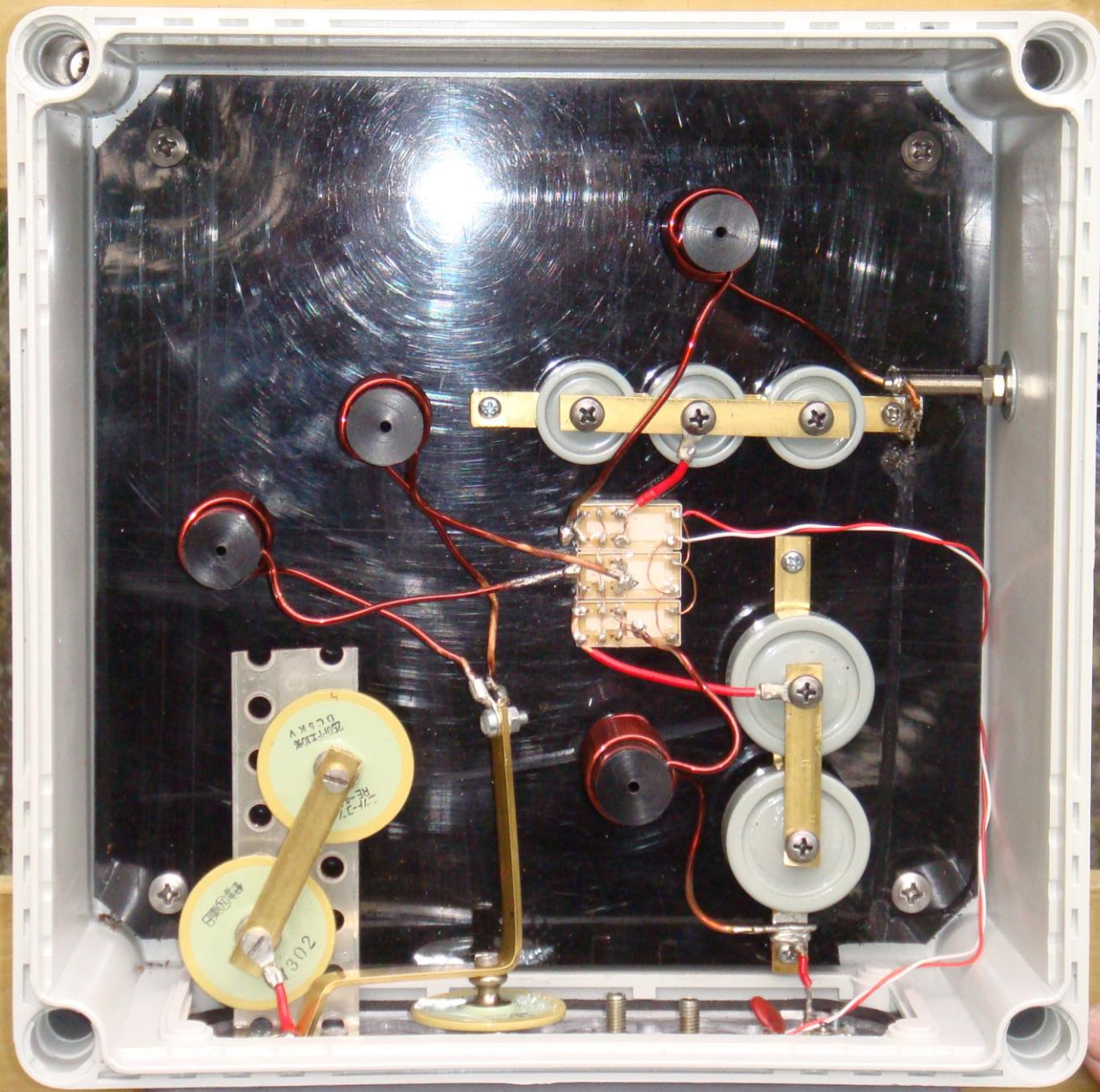
..the goal



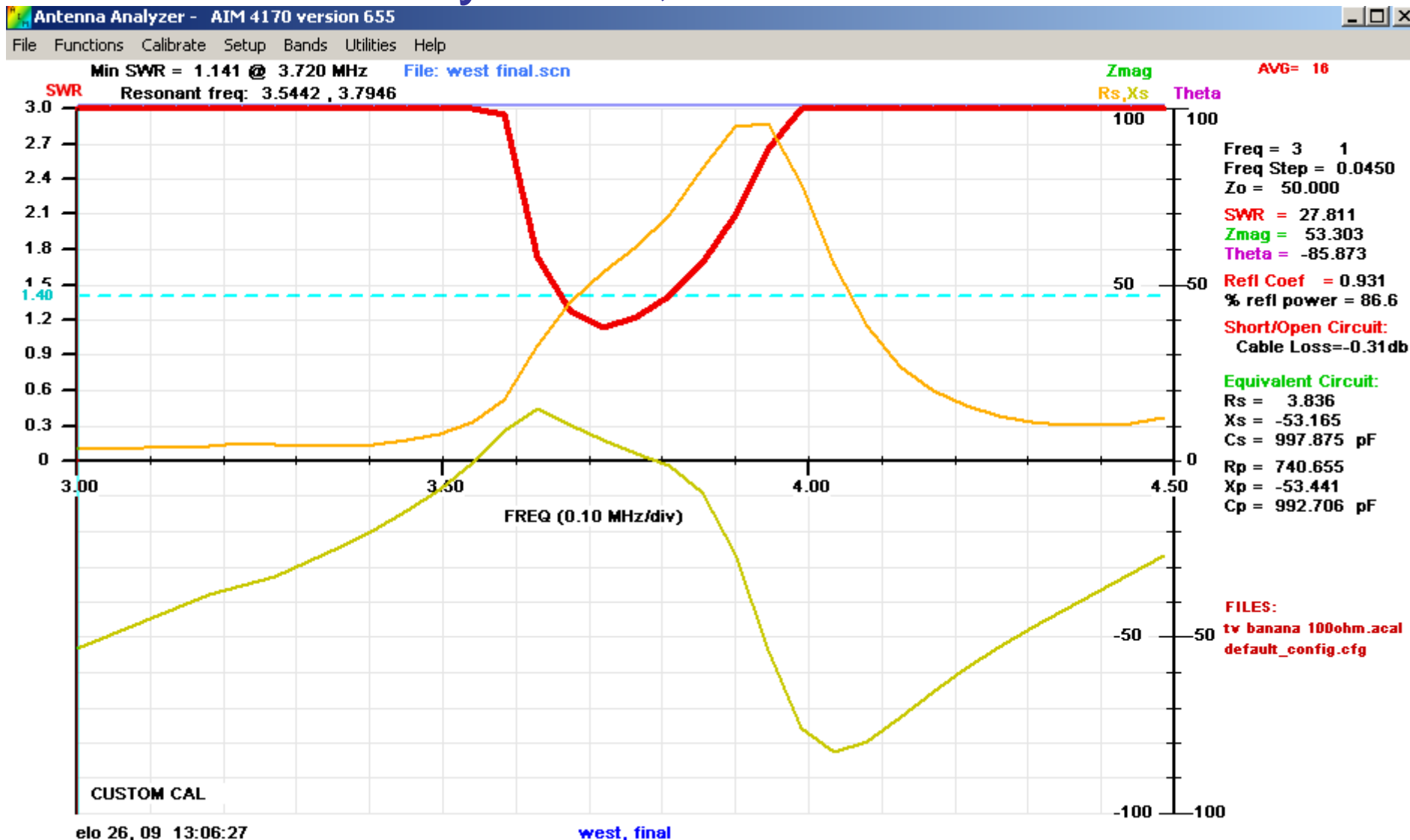
Phasing box, schematic

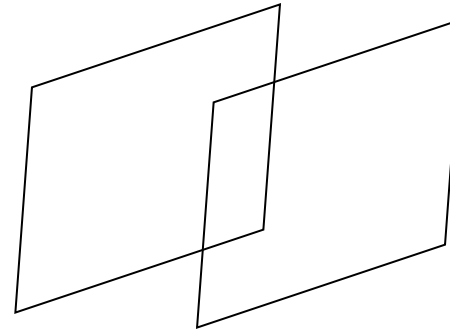
phasing angle 105 degrees





Array SWR, direction west





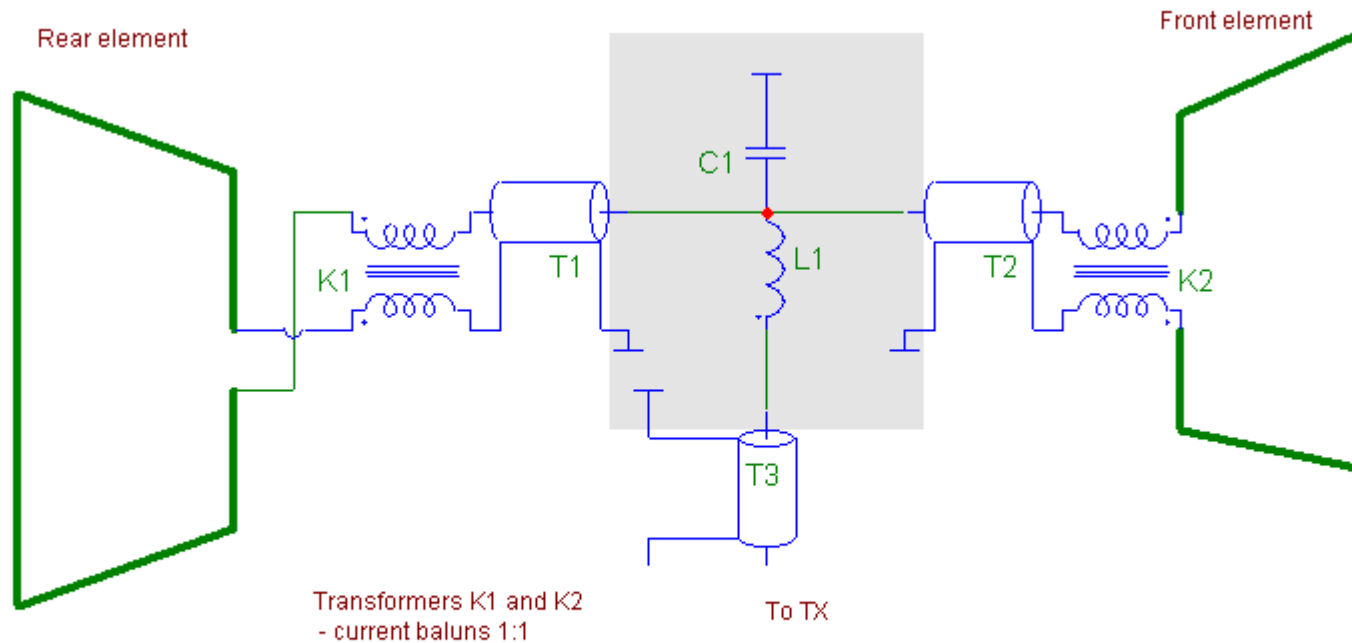
Quad improved

This is an analysis about possibility to apply Opposite Voltage Feed system to 2-element Quad and study what advantage it would provide.

Pekka Ketonen

Concept of Opposite Voltage fed 2-el Quad

top view



14.1.2011
OH1TV

Traditional Quad on 15m

file: 2q21

Traditional

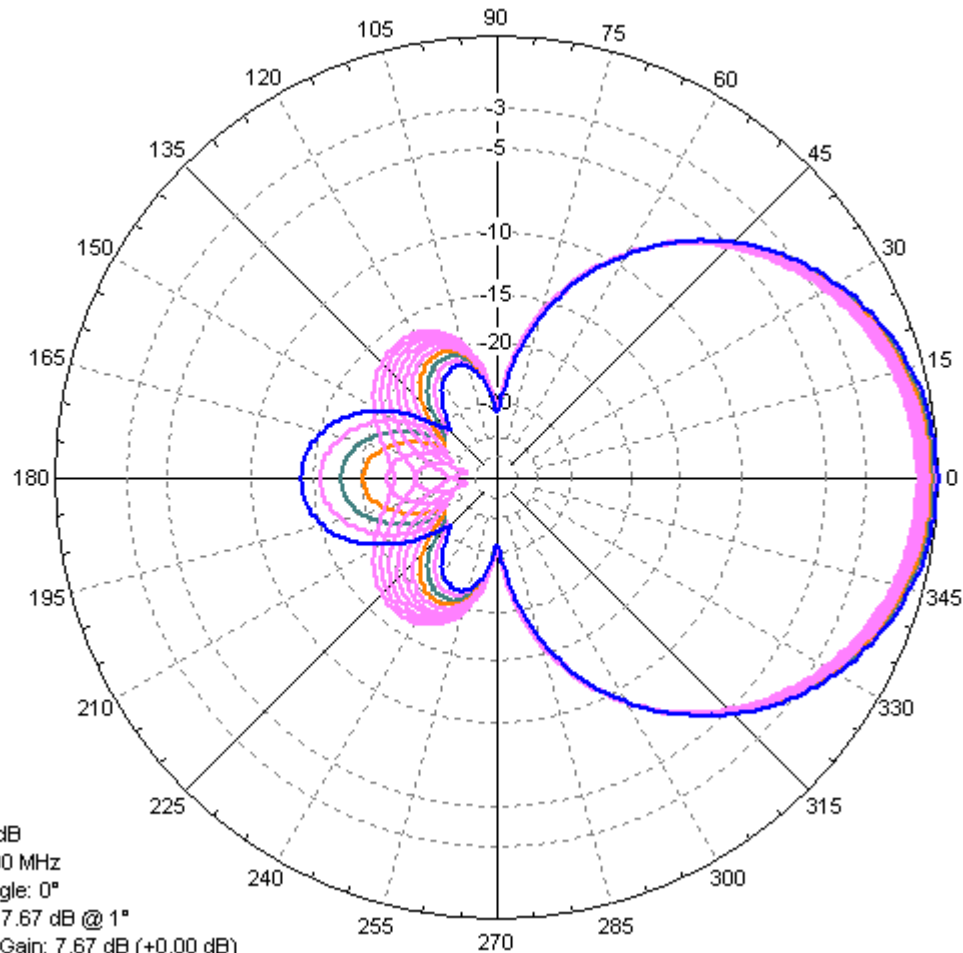
Spacing 230cm

Driven 358x358cm

Reflector 376x376cm

Wire 2mm cu

Sweep is 21.00-
21.45MHz in 50kHz
steps



OVF-Quad

2q21-ovf, same dimensions as in traditional Quad before

2q21-ovf

Spacing 230cm

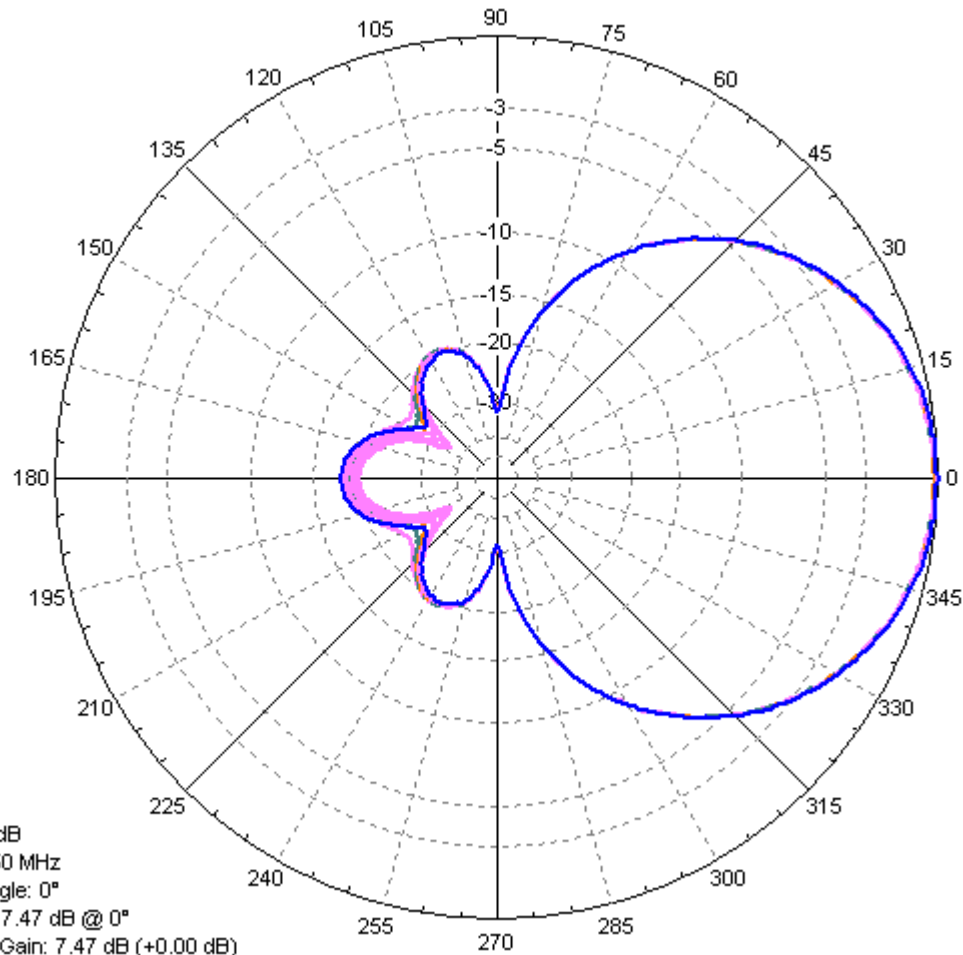
Driven 358x358cm

Reflector 376x376cm

Wire 2mm cu

Fine tuning with coils at
the feedpoints

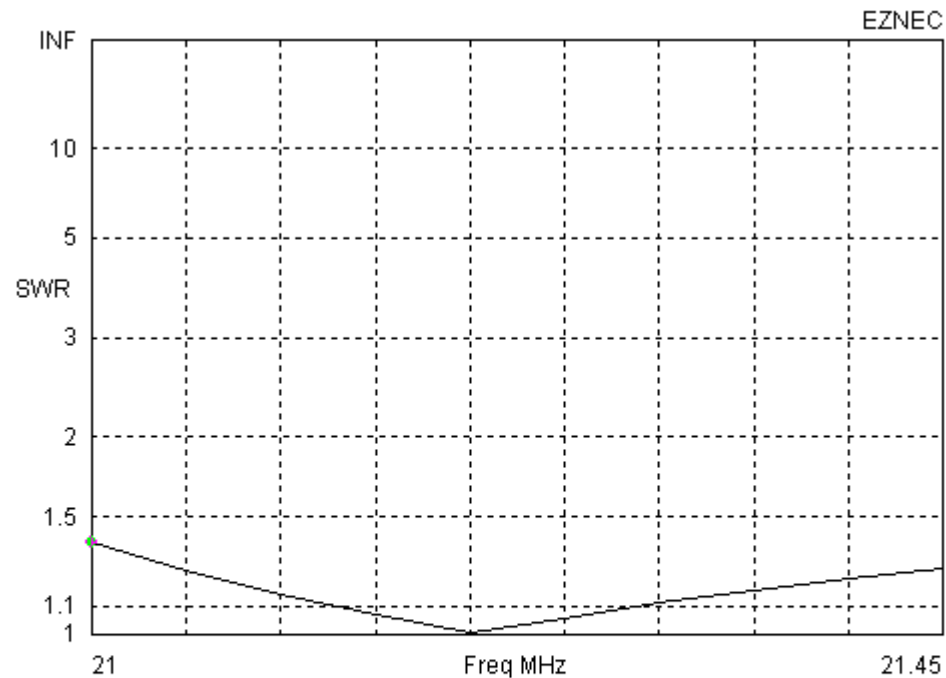
Sweep is 21.00-
21.45MHz in 50kHz
steps



Traditional Quad

L-match used

Sweep is 21.00-
21.45MHz in 50kHz
steps



Freq 21 MHz
SWR 1.37
Z 43.07 at 15.4 deg.
= 41.52 + j11.44 ohms
Refl Coeff 0.1543 at 119.42 deg.
= -0.07582 + j0.1344
Ret Loss 16.2 dB

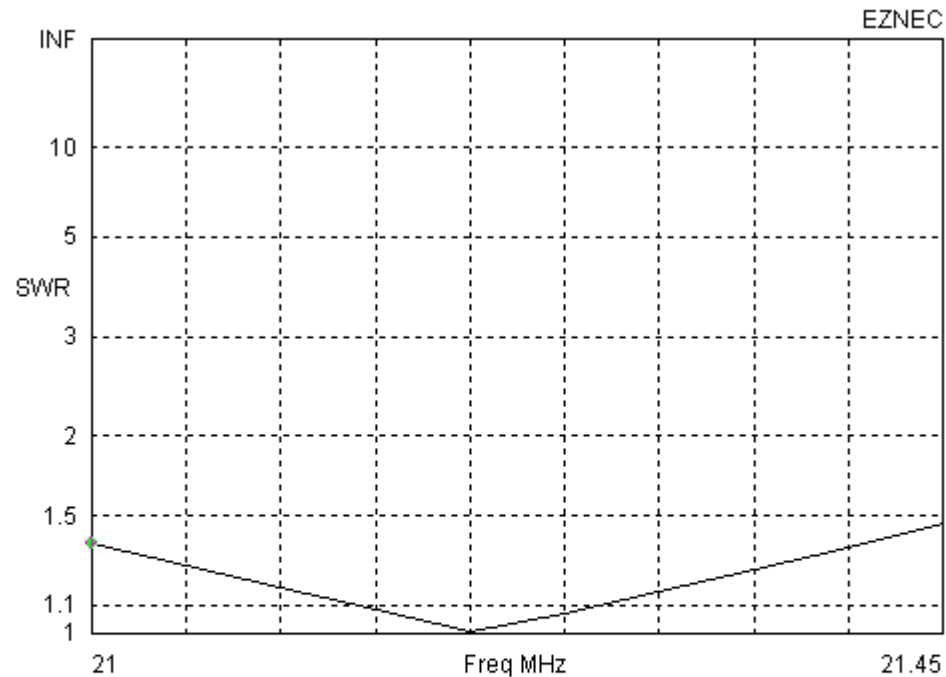
Source # 1
Z0 50 ohms

OVF-Quad

2q21-ovf, same dimensions as in traditional Quad before

L-match used

Sweep is 21.00-
21.45MHz in 50kHz
steps

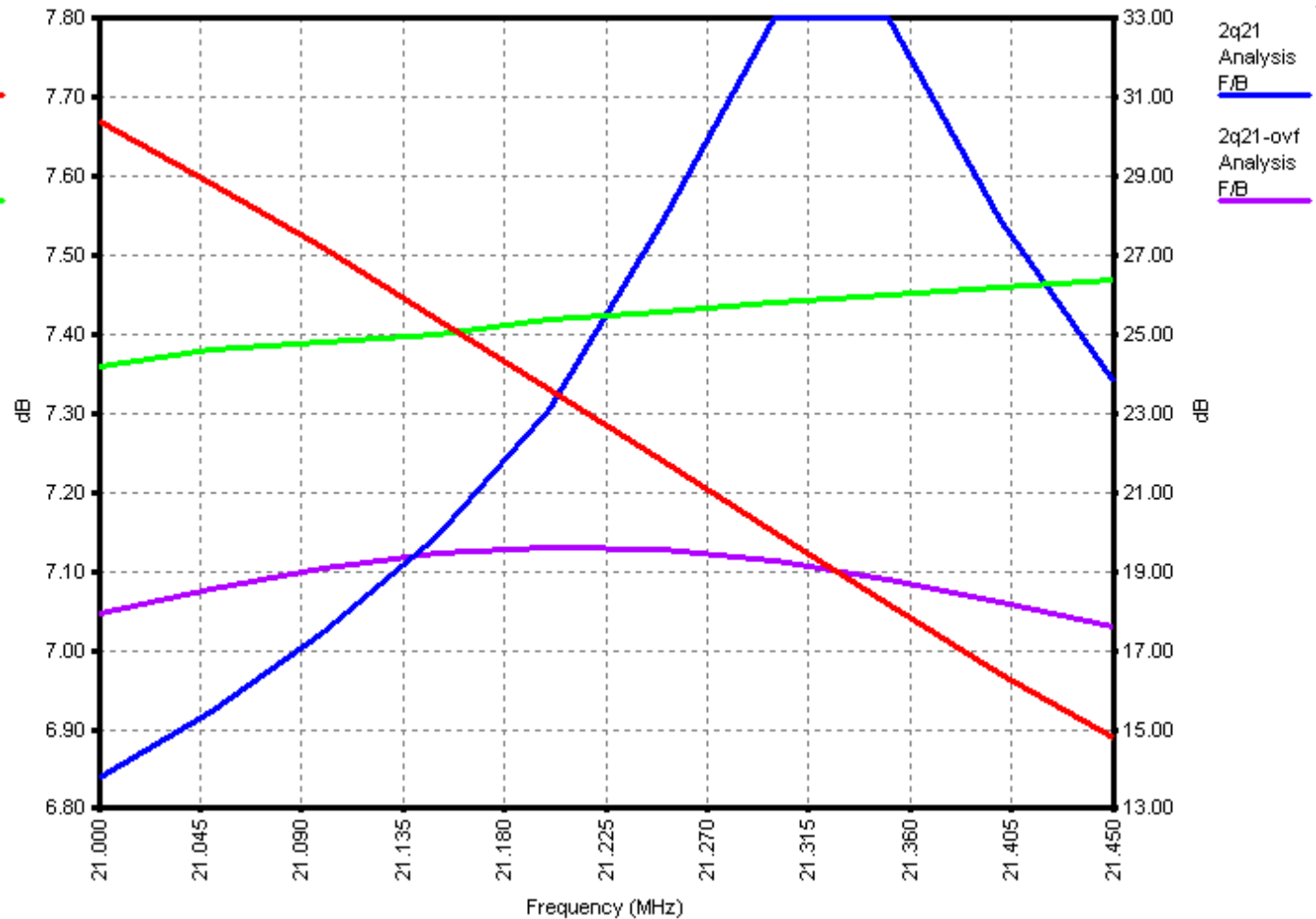


Freq 21 MHz
SWR 1.36
Z 59.58 at 14.09 deg.
= 57.79 + j 14.5 ohms
Refl Coeff 0.1514 at 54.11 deg.
= 0.08873 + j 0.1226
Ret Loss 16.4 dB

Source # 1
Z0 50 ohms

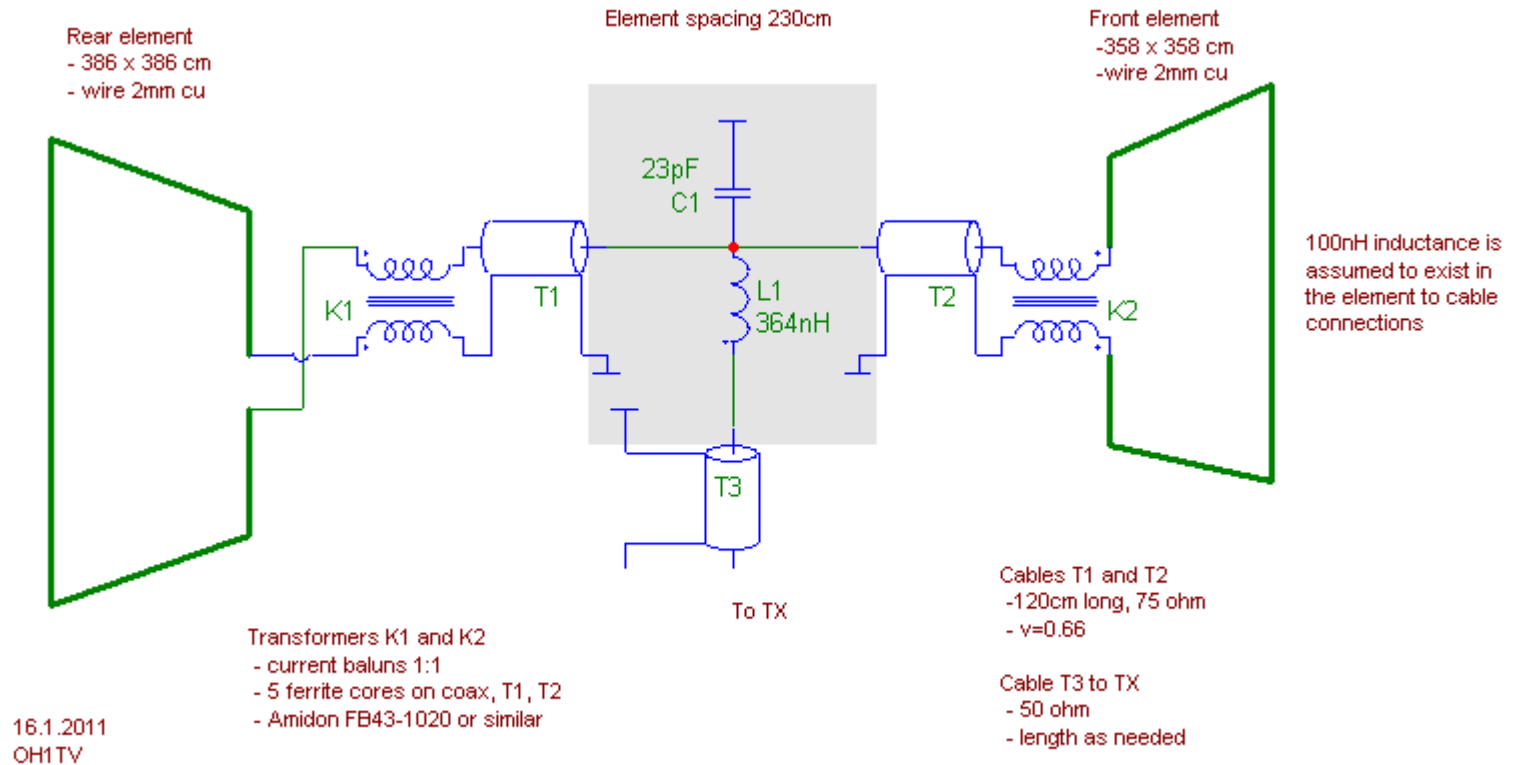
Gain and front-to-back

Comparison of traditional and OVF-Quad (same wire dimensions)



Optimized OVF-Quad

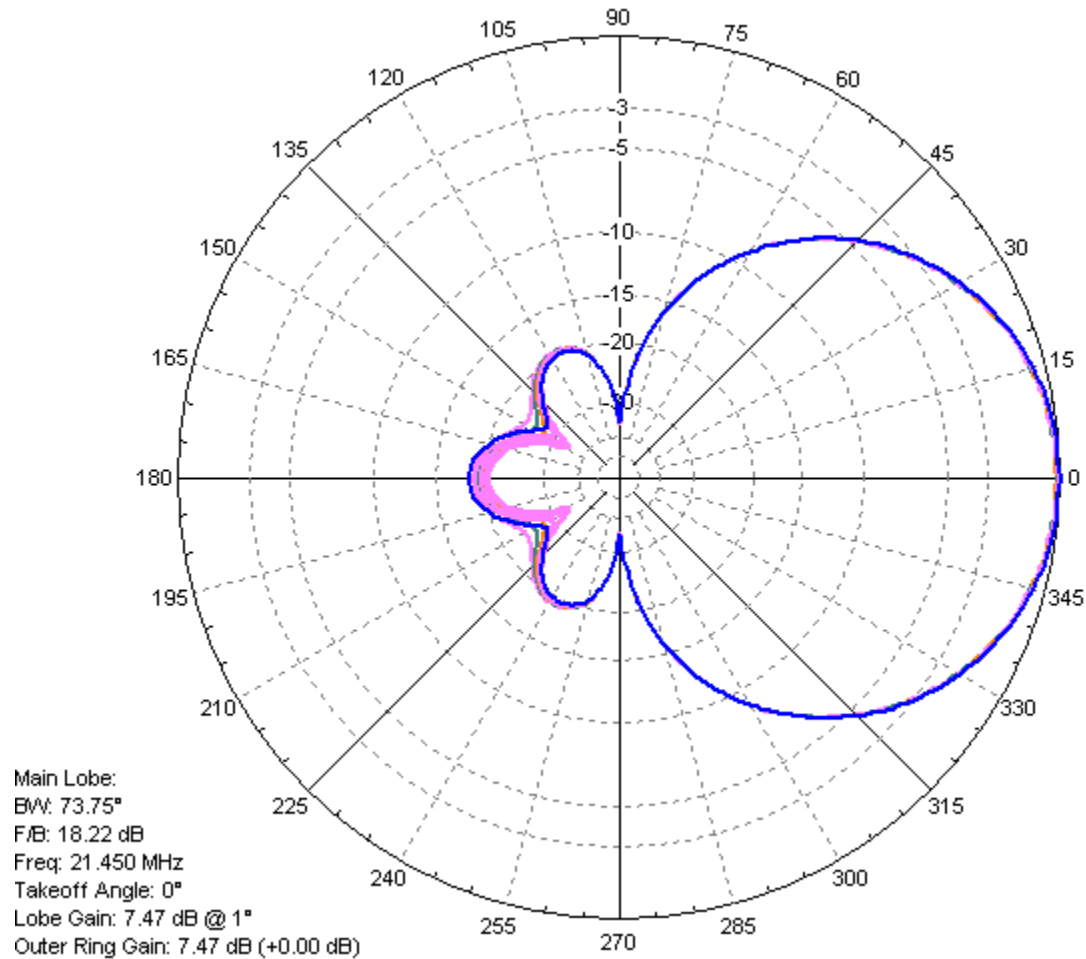
Eznec: 2q21-ovf2-75



16.1.2011
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Optimized OVF-Quad

Eznec: 2q21-ovf2-75



2q21-ovf2-75

Spacing 230cm

Driven 358x258cm

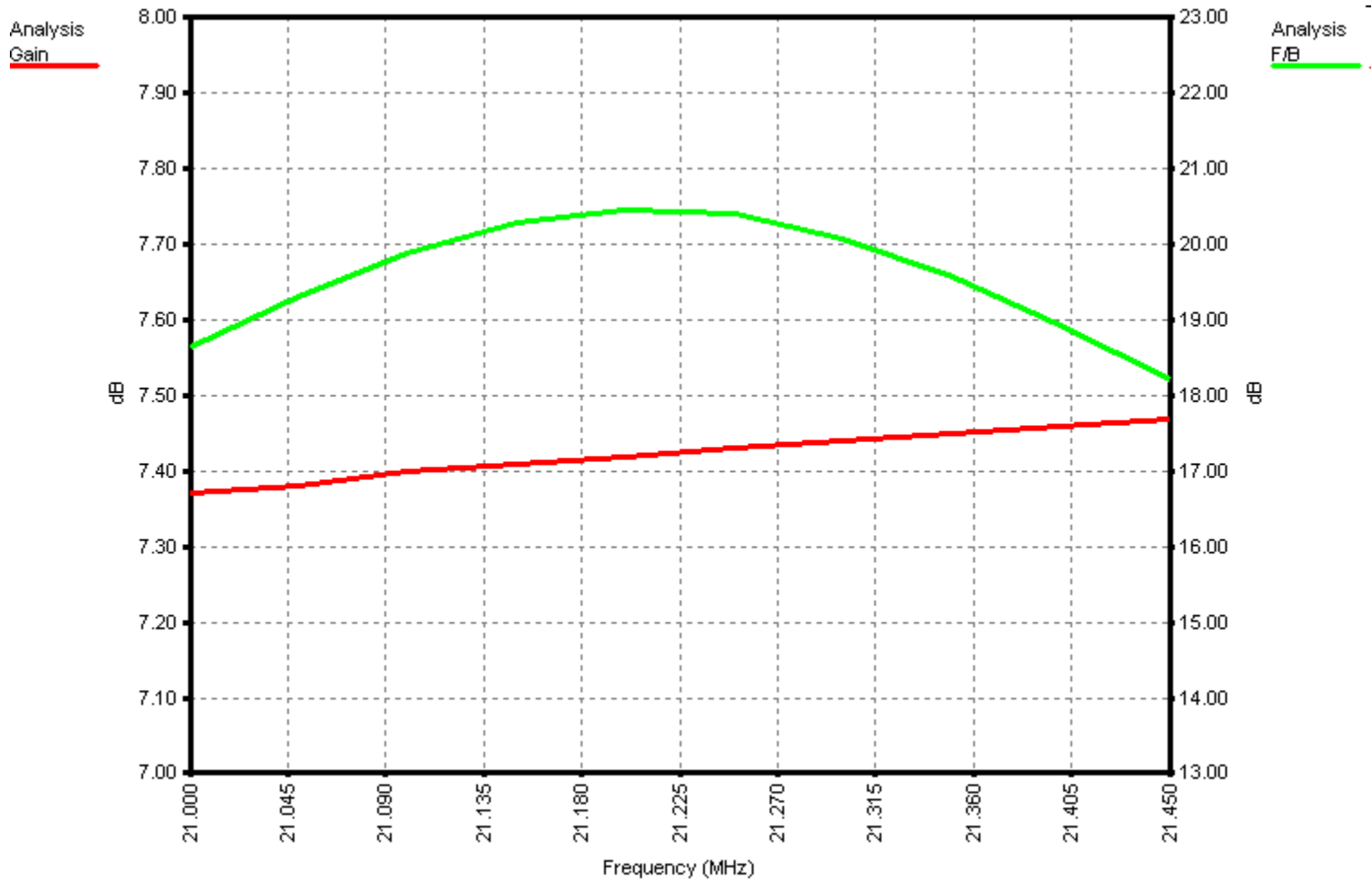
Reflector 386x386cm

Wire 2mm cu

+ 100nH coils at both
feedpoints

Optimized OVF-Quad

Eznec: 2q21-ovf2-75

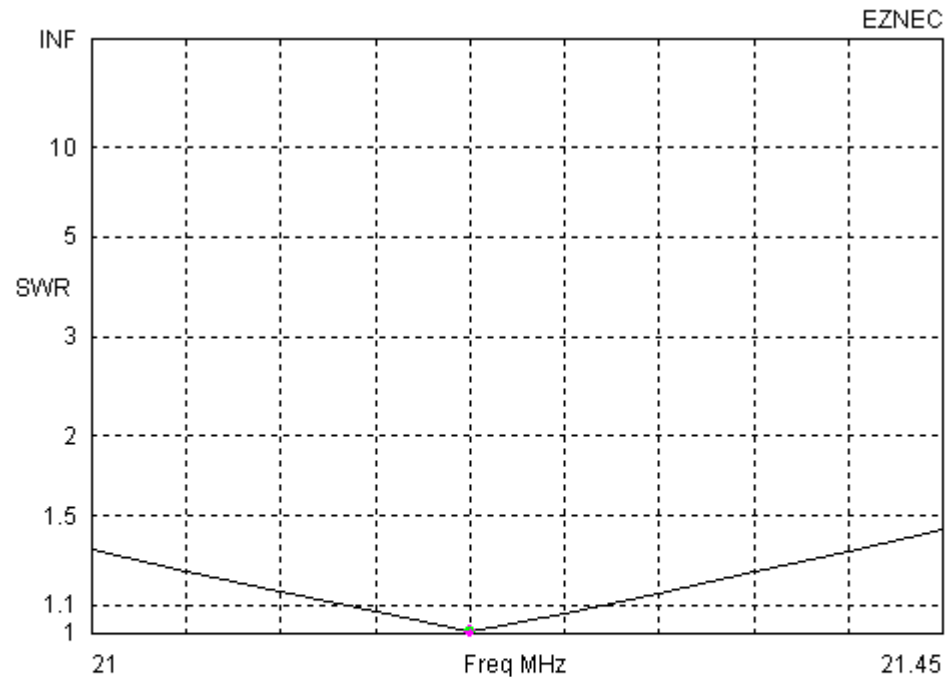


Optimized OVF-Quad

2q21-ovf2-75

L-match used

Sweep is 21.00-
21.45MHz in 50kHz
steps



Freq 21.2 MHz
SWR 1.006
Z 50.27 at 0.14 deg.
= 50.27 + j 0.1226 ohms
Refl Coeff 0.002943 at 24.48 deg.
= 0.002678 + j 0.001219
Ret Loss 50.6 dB

Source # 1
Z0 50 ohms

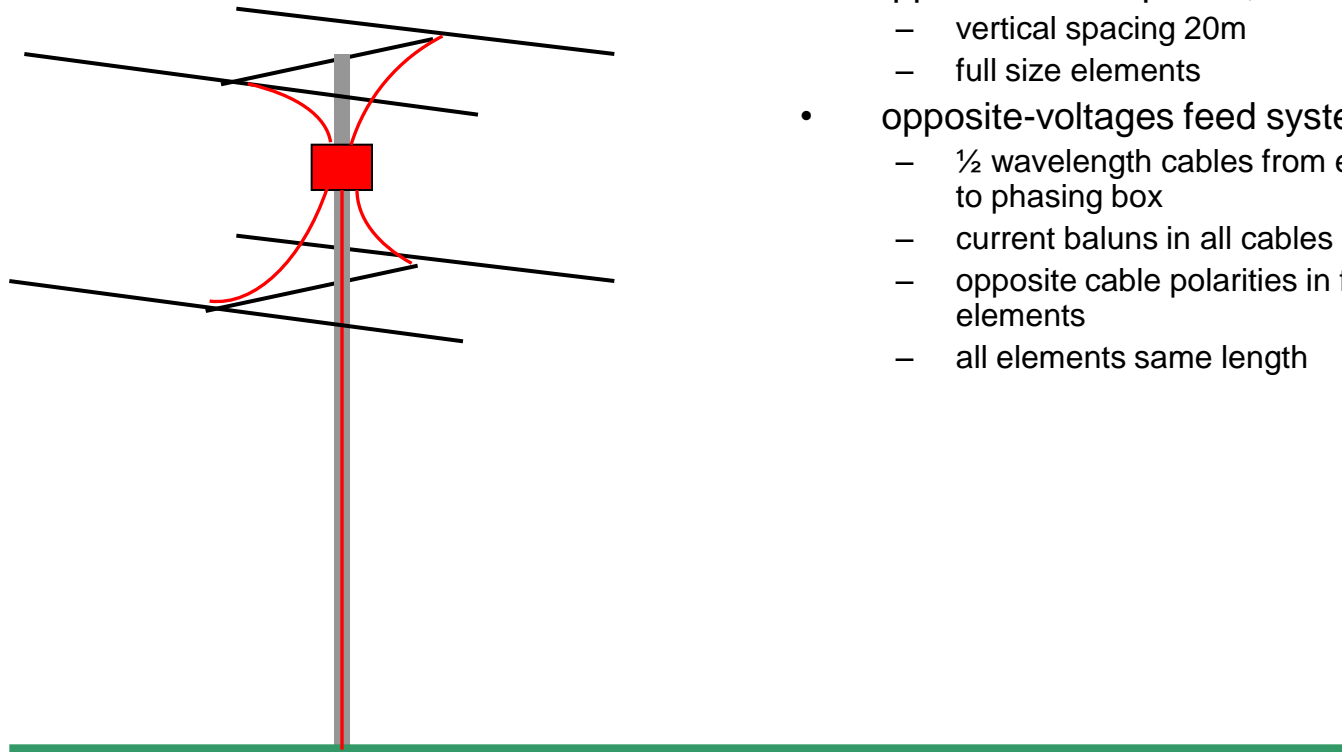
Conclusions

- Opposite voltage feed makes 2-el Quad less frequency dependent
 - Gain variation over 21MHz band is only 0.1dB
 - 0.8dB in traditional parasitic Quad
 - F/B variation is also smaller, from 18.2 to 20.5dB, window being 2.3dB
 - 14-38dB in traditional parasitic Quad
 - SWR is slightly higher than in traditional Quad at upper end of band
 - but SWR is still less than 1.5
- 75 ohm coax cable is good for feeding the elements.
 - cables to the elements shall have equal lengths
 - 2x120cm cables $v=0.66$ were used as element spacing was 230cm
- L-match can be used to match the antenna into 50ohm cable
 - T-connection and matching unit can be integrated
- Complexity of Quad is only slightly increased in comparison to traditional Quad



Opposite-voltage fed array for 40m
at OH1NX

2 over 2 phased array for 40m



- upper antenna up 49m, lower ant 29m
 - vertical spacing 20m
 - full size elements
- opposite-voltages feed system
 - $\frac{1}{2}$ wavelength cables from each element to phasing box
 - current baluns in all cables
 - opposite cable polarities in front and rear elements
 - all elements same length

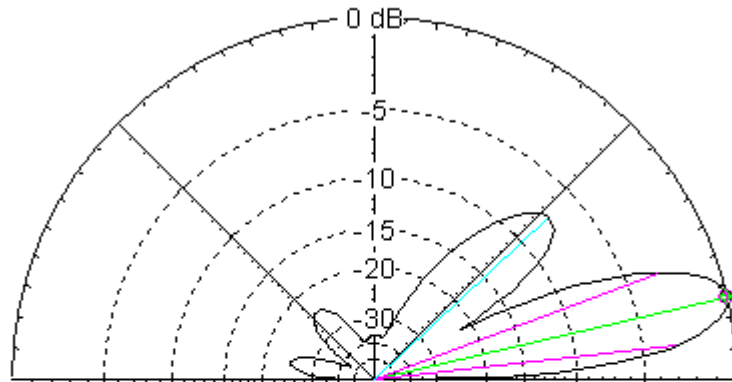
Features

- Good F/B over the whole band
 - Equal current amplitudes in all elements
 - Low vertical side lobes in DX-position because of stacking
 - Two frequency settings, 7000-7100 and 7100-7200kHz
 - Both settings cover the whole 40m band quite well
- Wideband (less so in the local position)
- Switchable take-off-angle. DX and Local
- The structure allows instant 180deg direction switching
 - even it was not implemented in the first phase.

Position 7050kHz DX, 13deg TOA

Total Field

EZNEC



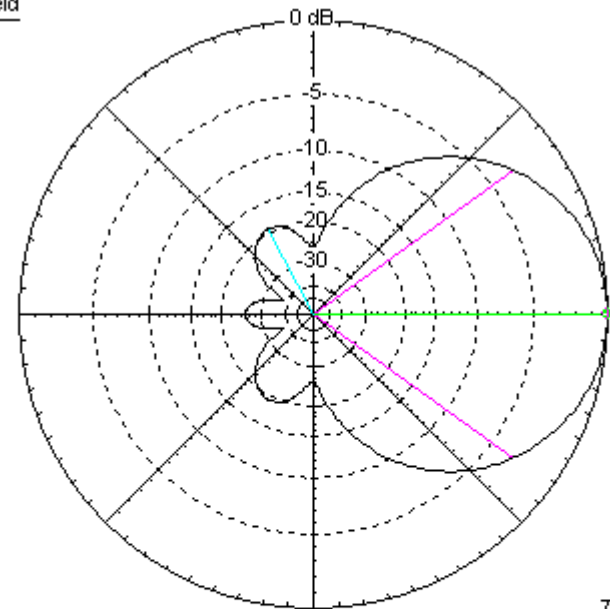
7.05 MHz

Elevation Plot		Cursor Elev	13.0 deg.
Azimuth Angle	0.0 deg.	Gain	14.06 dBi
Outer Ring	14.06 dBi		0.0 dBmax

Slice Max Gain	14.06 dBi @ Elev Angle = 13.0 deg.
Beamwidth	14.1 deg.; -3dB @ 6.5, 20.6 deg.
Sidelobe Gain	6.83 dBi @ Elev Angle = 43.0 deg.
Front/Sidelobe	7.22 dB

Total Field

EZNEC



7.05 MHz

Azimuth Plot		Cursor Az	0.0 deg.
Elevation Angle	13.0 deg.	Gain	14.06 dBi
Outer Ring	14.06 dBi		0.0 dBmax

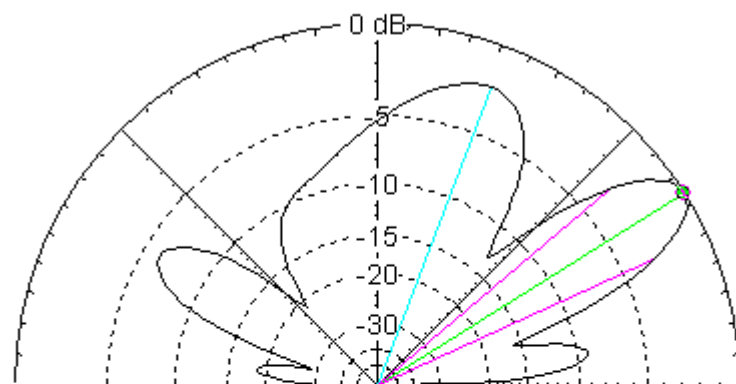
Slice Max Gain	14.06 dBi @ Az Angle = 0.0 deg.
Front/Back	25.08 dB
Beamwidth	71.0 deg.; -3dB @ 324.5, 35.5 deg.
Sidelobe Gain	-5.08 dBi @ Az Angle = 118.0 deg.
Front/Sidelobe	19.13 dB

Position Local, 32deg TOA

7050kHz 7150kHz

Total Field

EZNEC

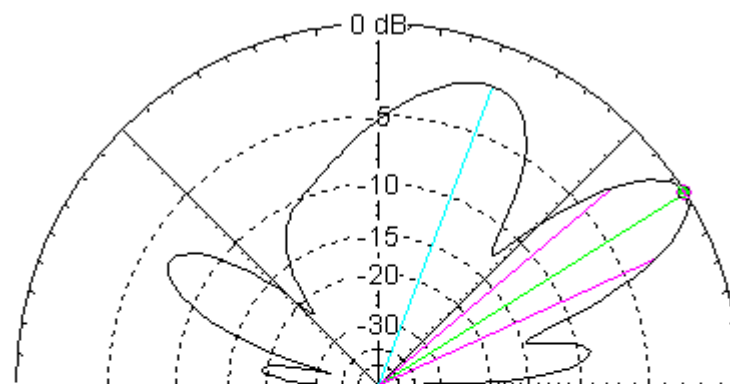


7.05 MHz

Elevation Plot		Cursor Elev	32.0 deg.
Azimuth Angle	0.0 deg.	Gain	11.13 dBi
Outer Ring	11.13 dBi		0.0 dBmax
Slice Max Gain	11.13 dBi @ Elev Angle = 32.0 deg.		
Beamwidth	15.7 deg.; -3dB @ 24.6, 40.3 deg.		
Sidelobe Gain	8.97 dBi @ Elev Angle = 69.0 deg.		
Front/Sidelobe	2.17 dB		

Total Field

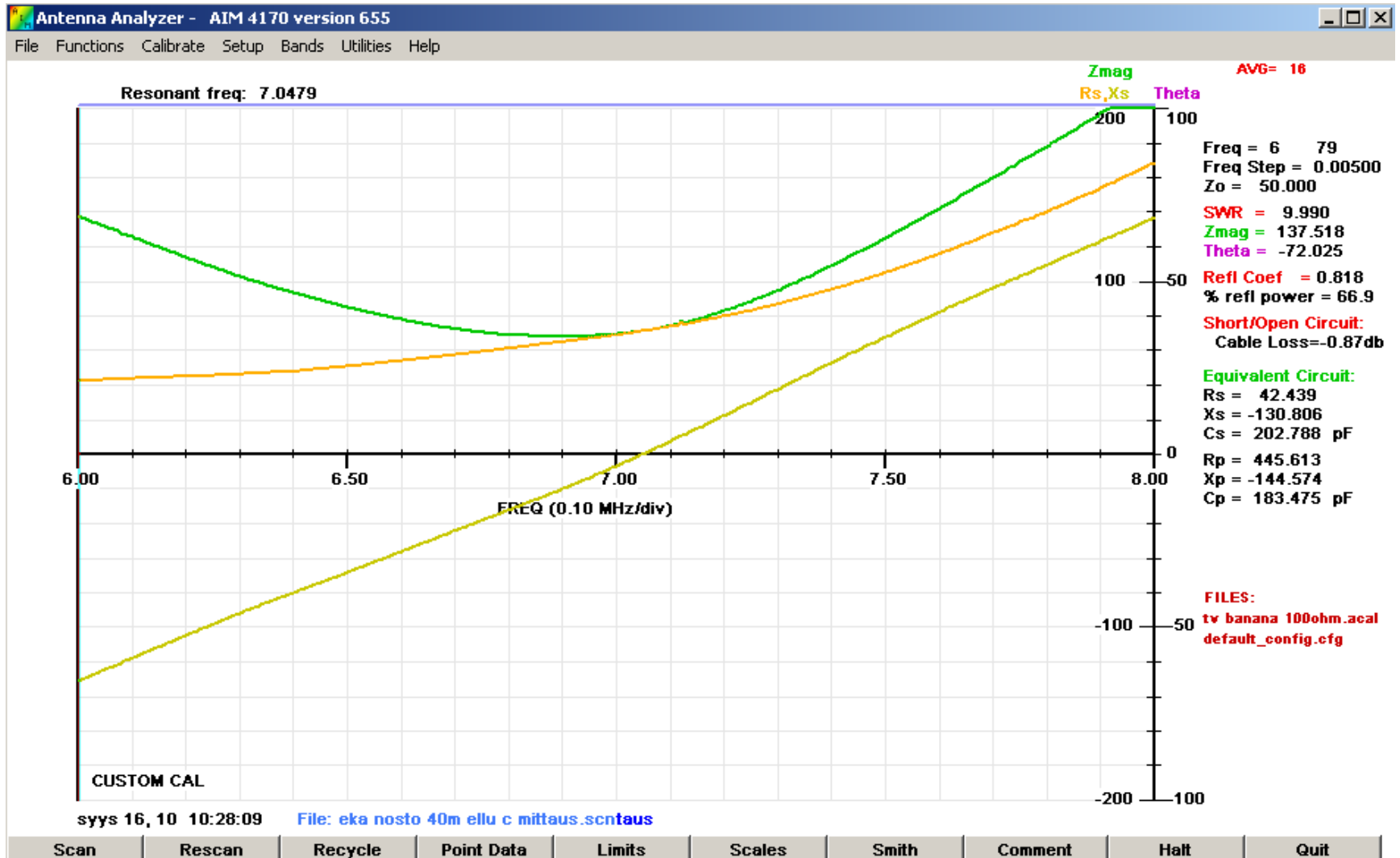
EZNEC



7.05 MHz

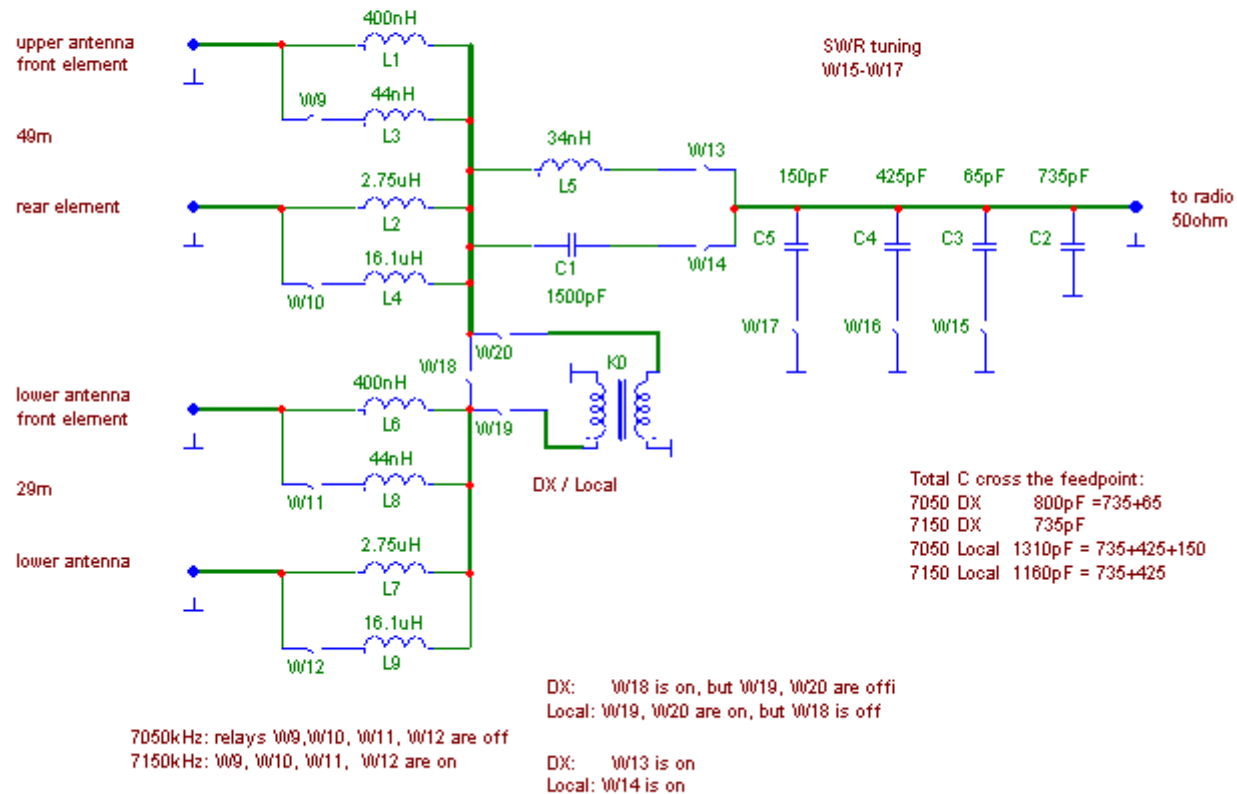
Elevation Plot		Cursor Elev	32.0 deg.
Azimuth Angle	0.0 deg.	Gain	11.19 dBi
Outer Ring	11.19 dBi		0.0 dBmax
Slice Max Gain	11.19 dBi @ Elev Angle = 32.0 deg.		
Beamwidth	15.8 deg.; -3dB @ 24.5, 40.3 deg.		
Sidelobe Gain	9.11 dBi @ Elev Angle = 69.0 deg.		
Front/Sidelobe	2.08 dB		

Measured feedpoint impedance of an element alone



Phasing and switching box

- 40m 2over2 at OH1NX
- all elements tuned to resonate at 7050kHz when alone
- feedcables from box to elements are 21.28m electrical length (measured), corresponds $\lambda/2$ on 7046.6kHz



V4c
2.1.2011
OH1TV

