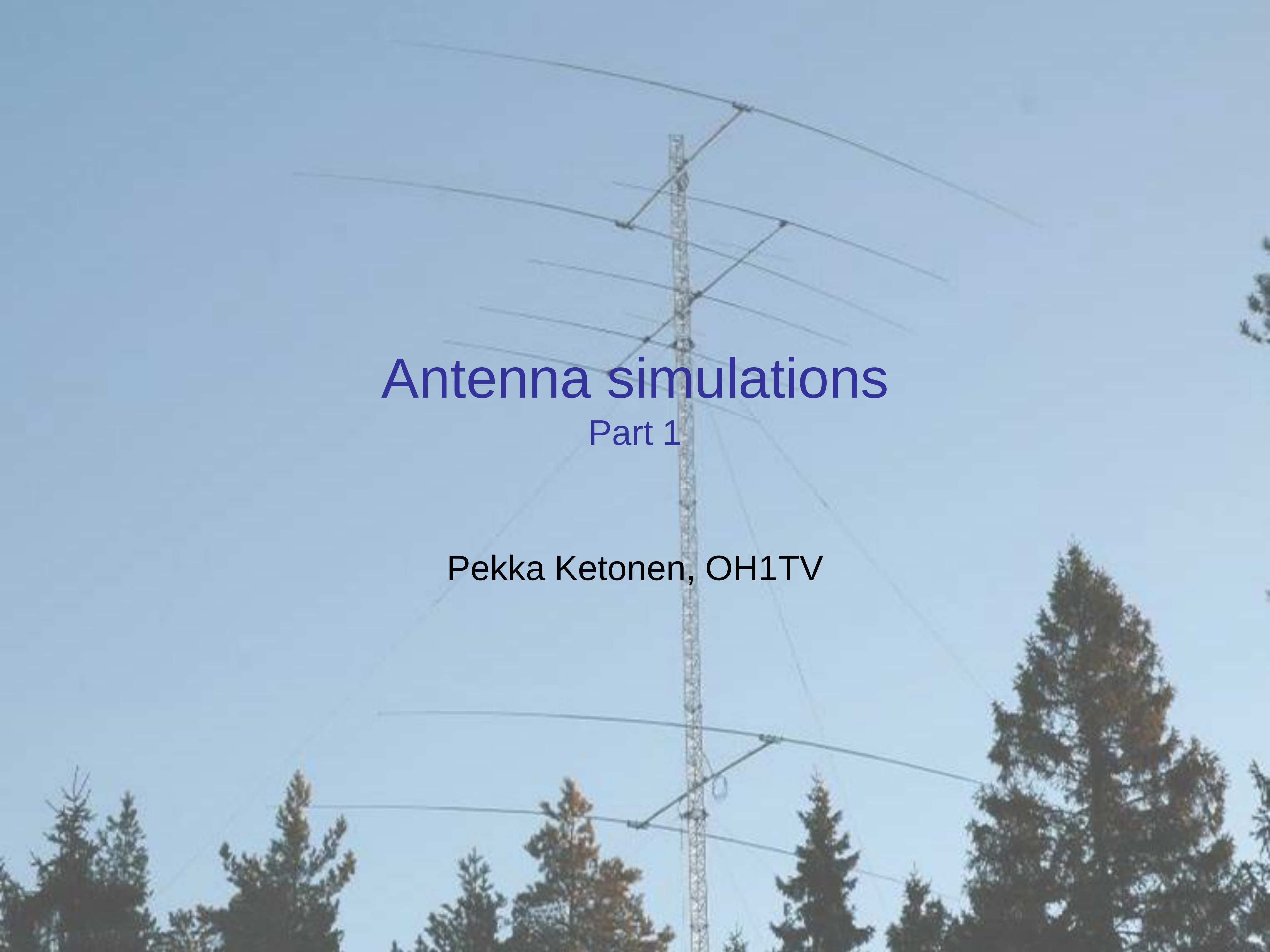


Antenna simulations

Part 1

Pekka Ketonen, OH1TV

Outline

Part 1

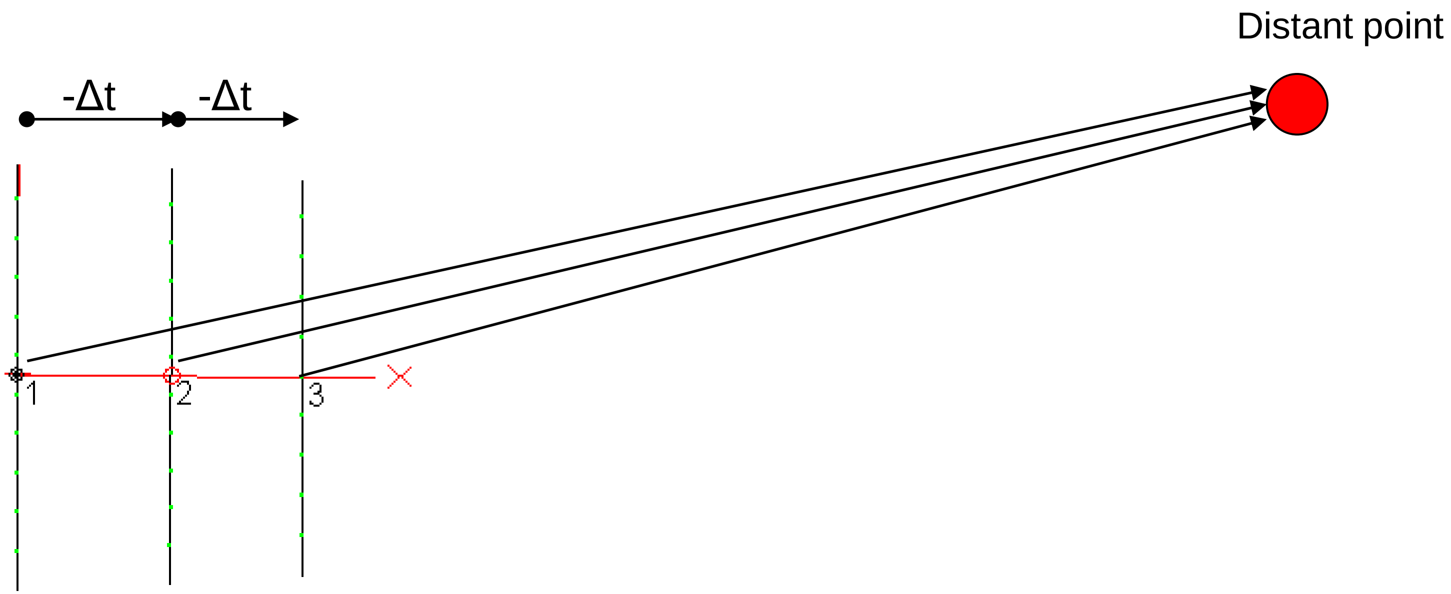
- Some principles in antenna design
  - typical steps in design process
- Opposite Voltage Feed
  - 2 phased verticals on 80m
  - 2 over 2 on 40m
  - Quad improved

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

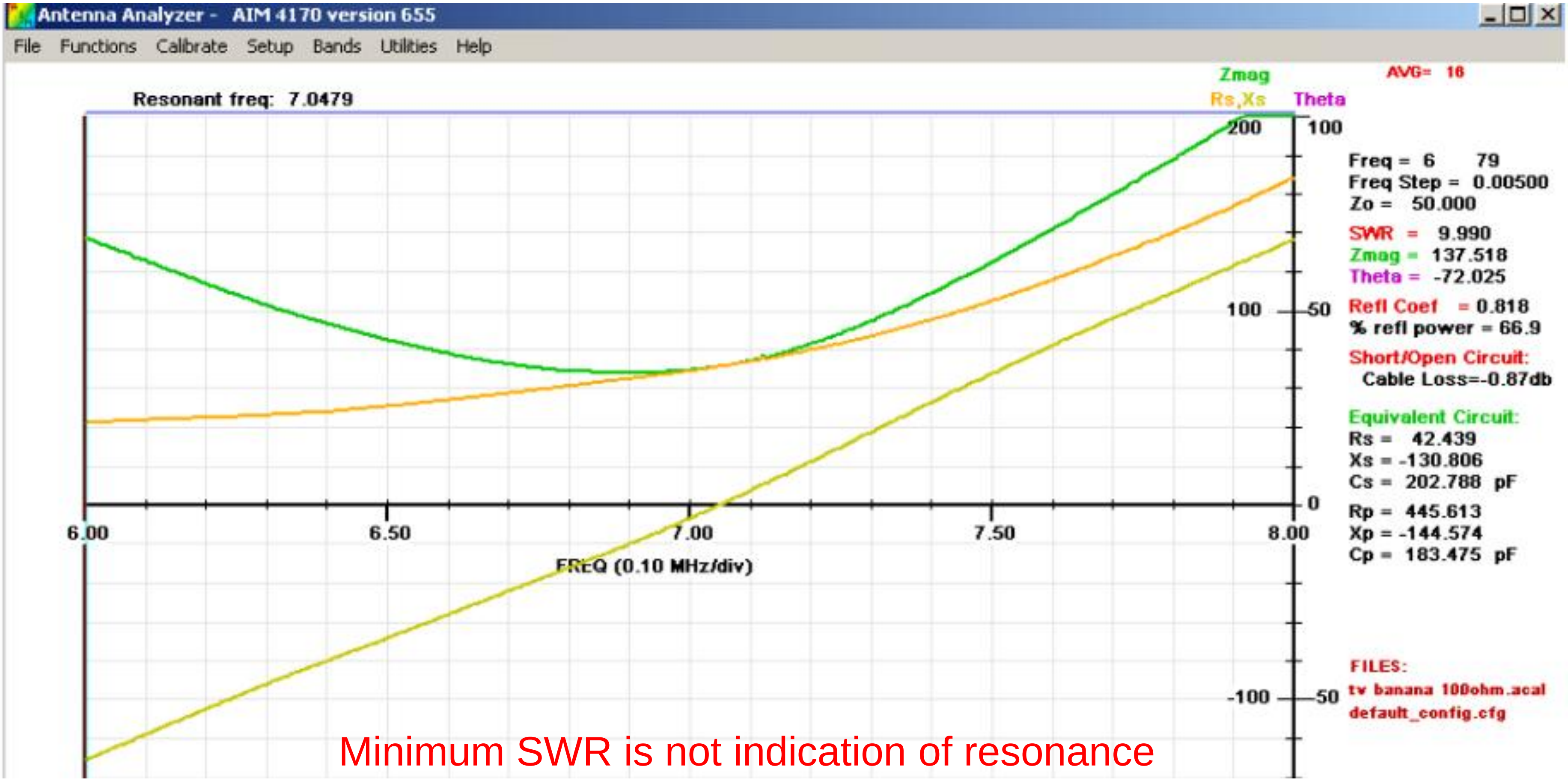
• By delaying the driving signals towards the front element we get signals into phase in distant point

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



Minimum SWR is not indication of resonance

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 degreases
      - Reflector resistances in series
      - **Antenna environment is the key**
    - Horizontal : losses increase when angle of radiation increases
      - Reflector resistances parallel

  - 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

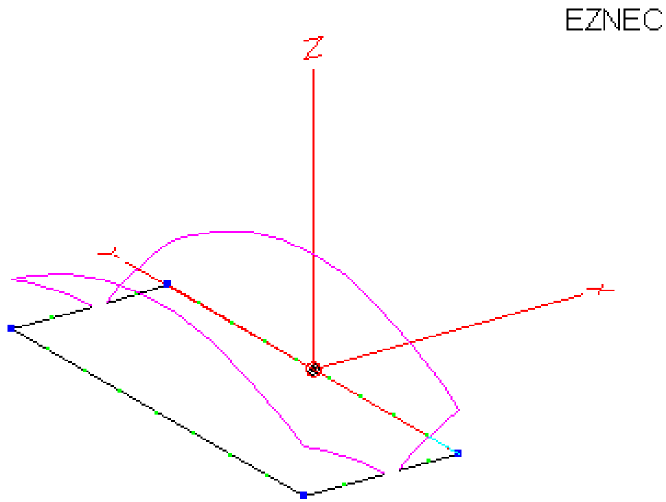
In practice this work is highly iterative

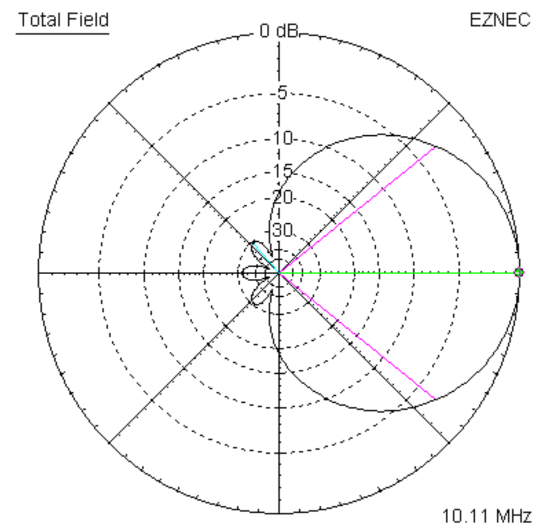
2.1. Radiation pattern

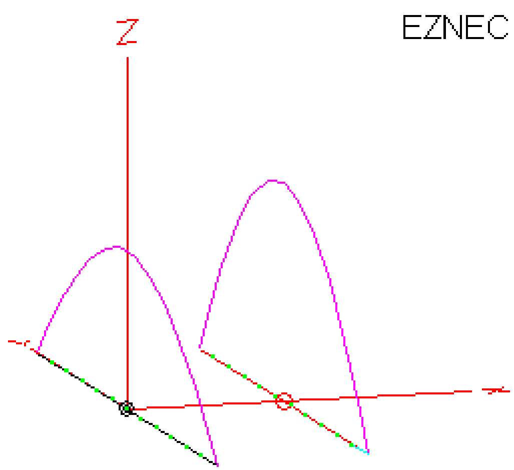
Depends on

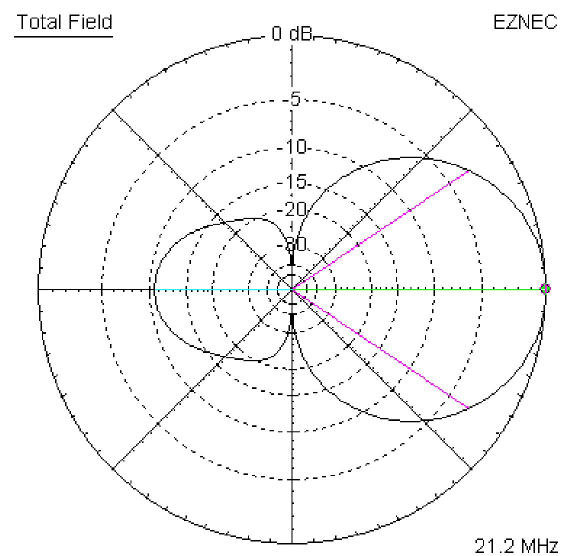
- Element locations, positions, geometry
  - Boom length
- Element current relations, amplitude and phase
- Element size and shape
  - 0.25-1.0 wave length or so
  - straight, square, round, V-shaped, U-shaped, and so on
  - non-tapered, tapered, thick, thin
- Amplitude distribution of current in element
  - 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

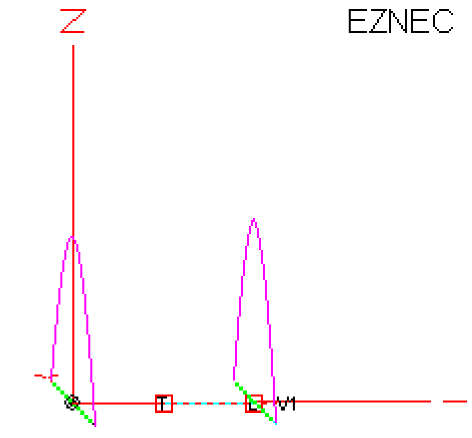


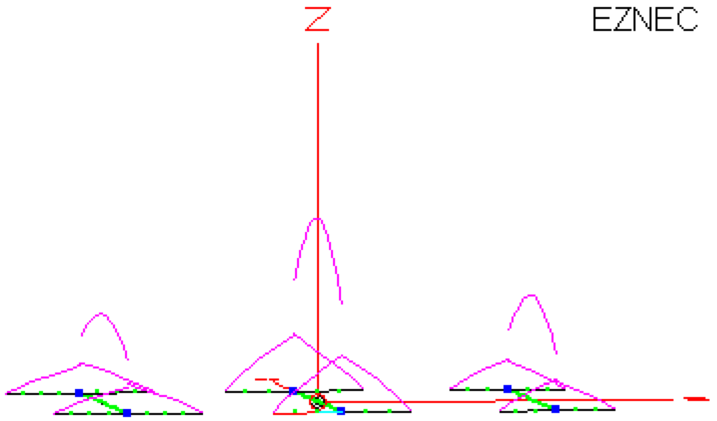


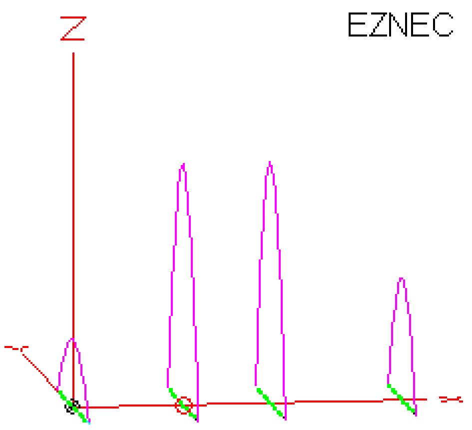


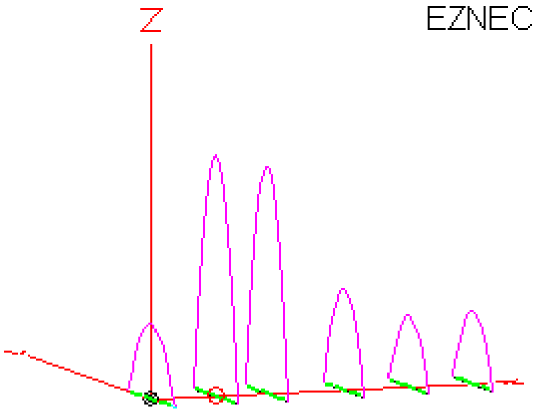


3.0.Current distribution between elements









3.1. Current distribution between elements How?

1. By current forcing, phased array
   1. ¼ λ 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

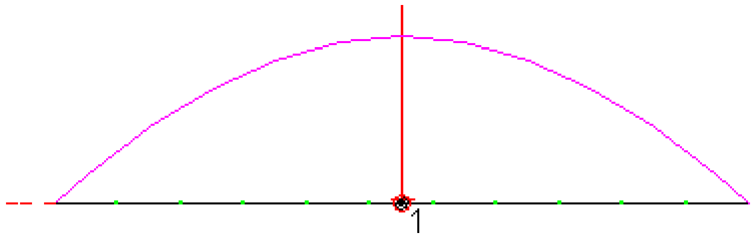
2. By mutual coupling, parasitic array
   1. With element detuning and distance to other elements we can control the element current amplitude and phase
   2. In multi-element array these interactions are complex and it is difficult to manage
   3. Certain “standard designs” exist

3. Combination of mutual coupling and voltage bias
   1. “Opposite voltage feed” by OH1TV

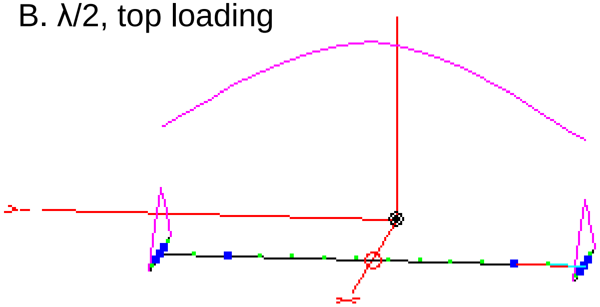
4. Combination of those above

3.2.Current distribution of an antenna element How?

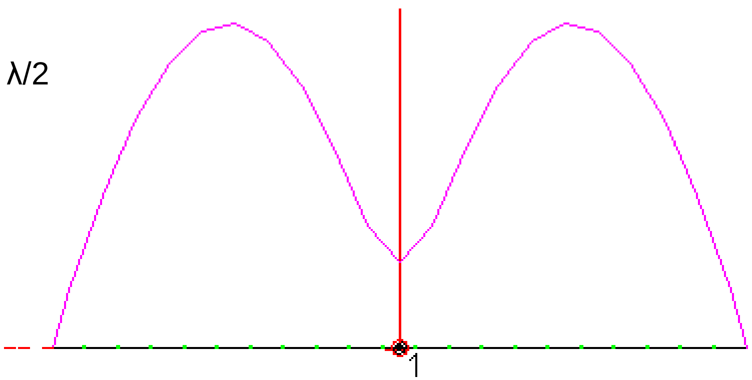
A. λ/2



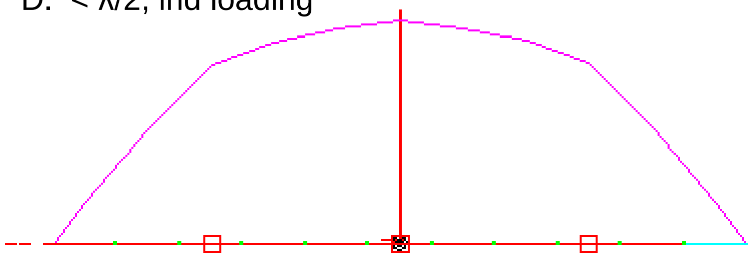
B. λ/2, top loading



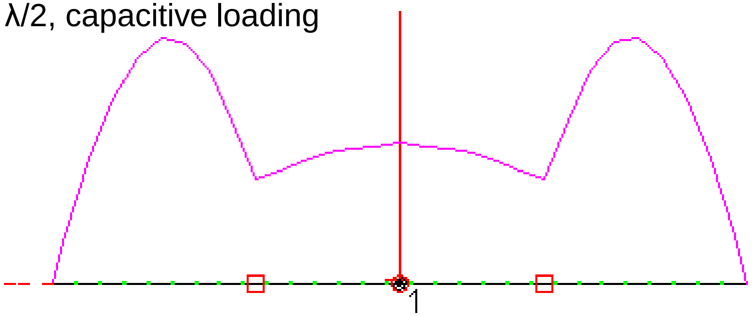
C. > λ/2



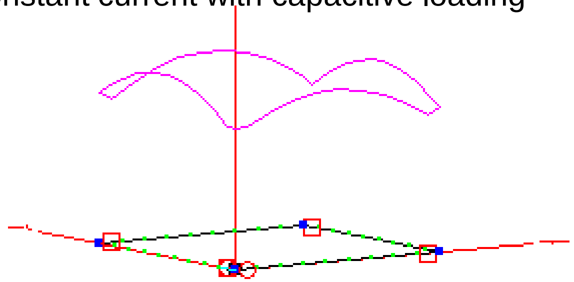
D. < λ/2, ind loading



E. < λ/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. ¼ wavelength cable, Zo=SQR(Z1xZ2)
    - May be difficult to find suitable cable

3. Reactive components can be removed
    - 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 components 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 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

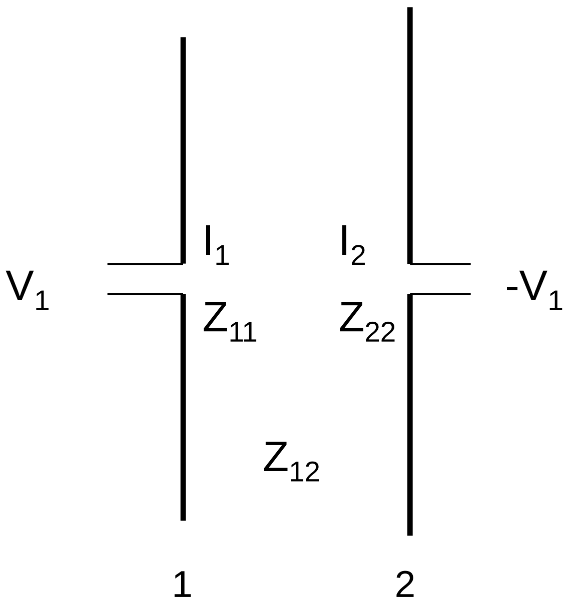
What is Opposite Voltage Feed?

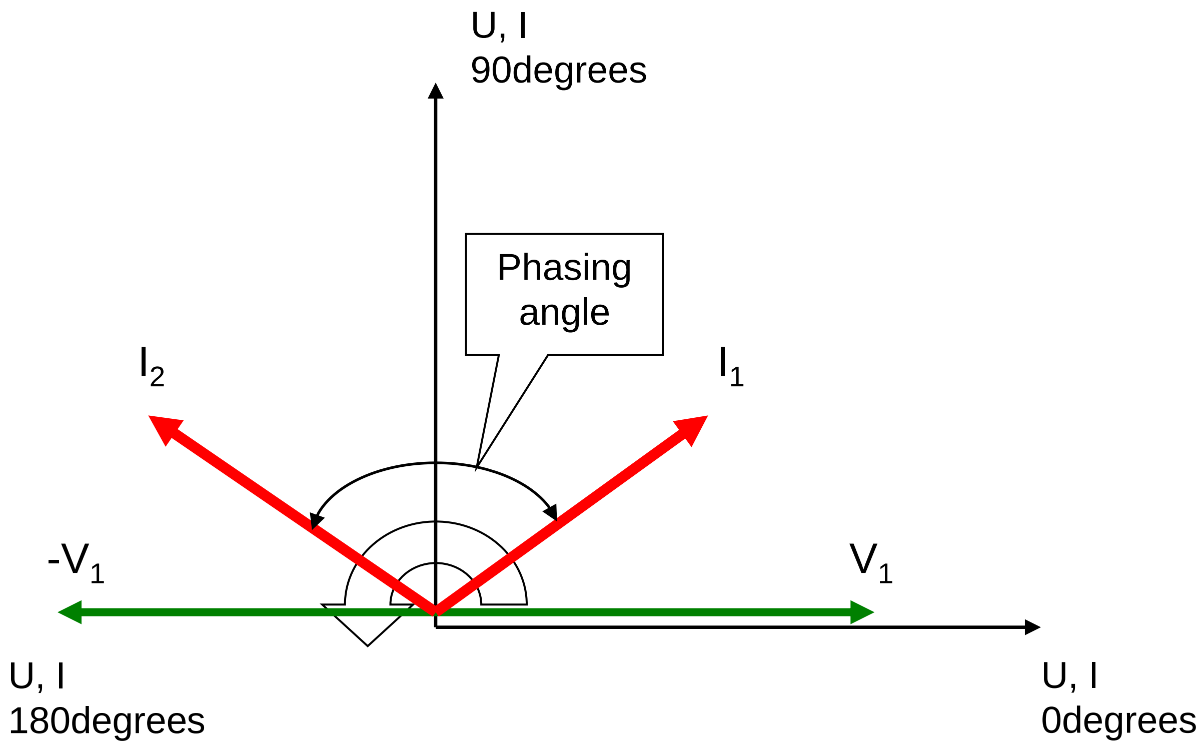
OVF is a method to feed 2-element antennas. It makes possible to adjust current amplitudes and phases so that good radiation pattern can be achieved. The main advantage is insensitivity of radiation pattern to frequency change. The concept is that equal amplitude but opposite phase voltages are brought 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.

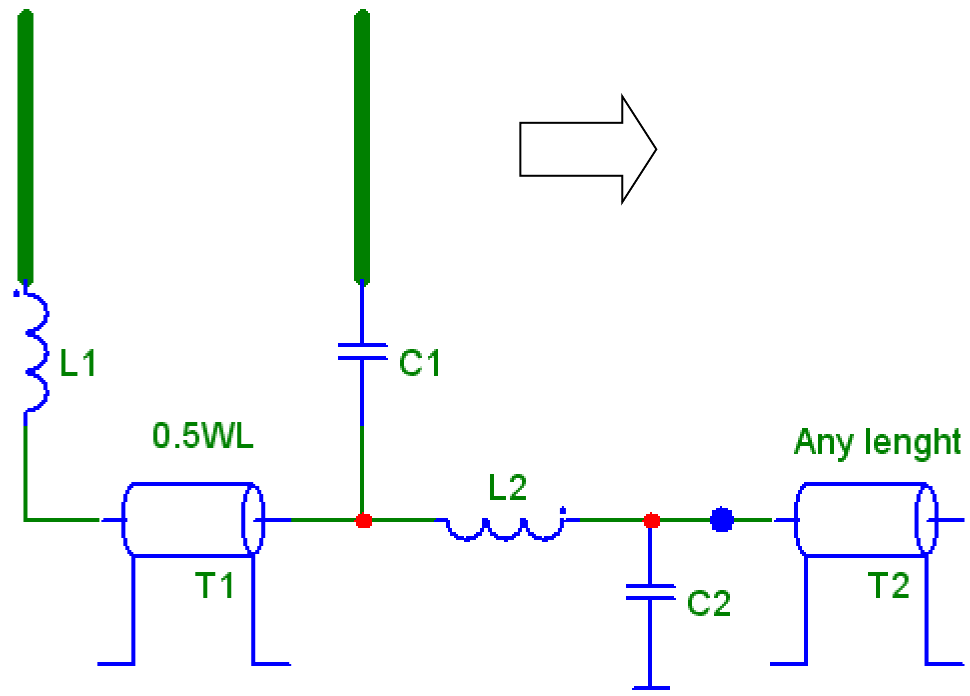
Voltage and current vectors





Two element vertical

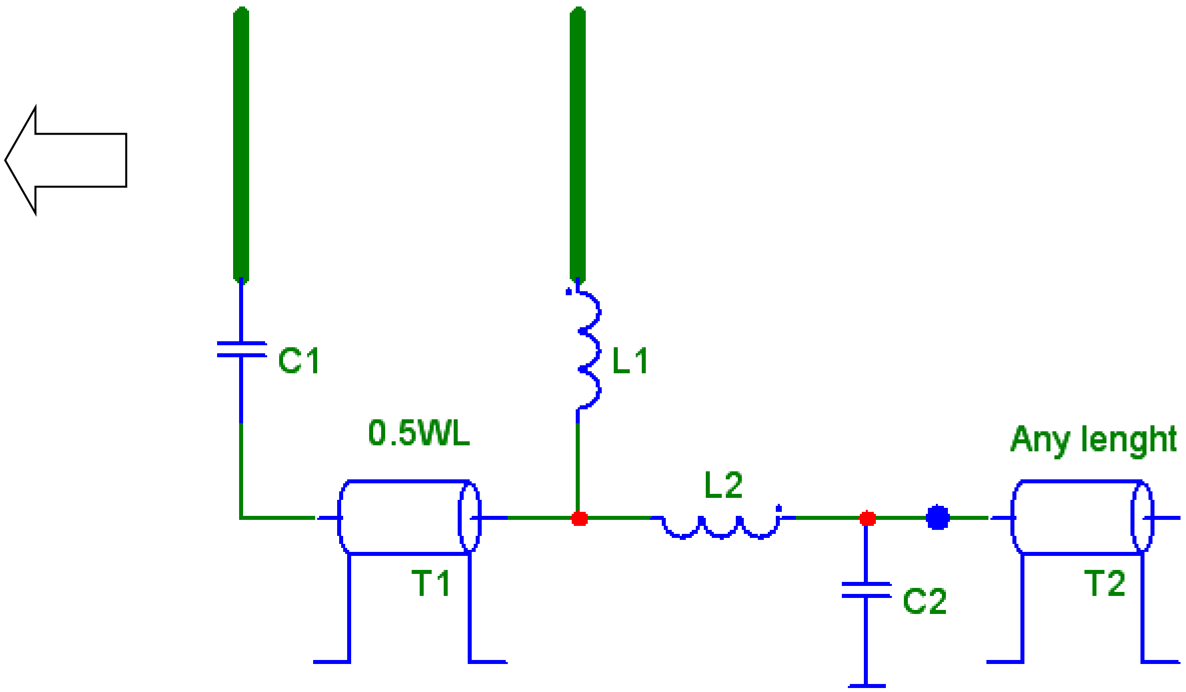
Spacing of verticals 0.15-0.25 wavelengths
Verticals radiators 0.25 wavelength long



Opposite voltage fed array by OH1TV

Two element vertical

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

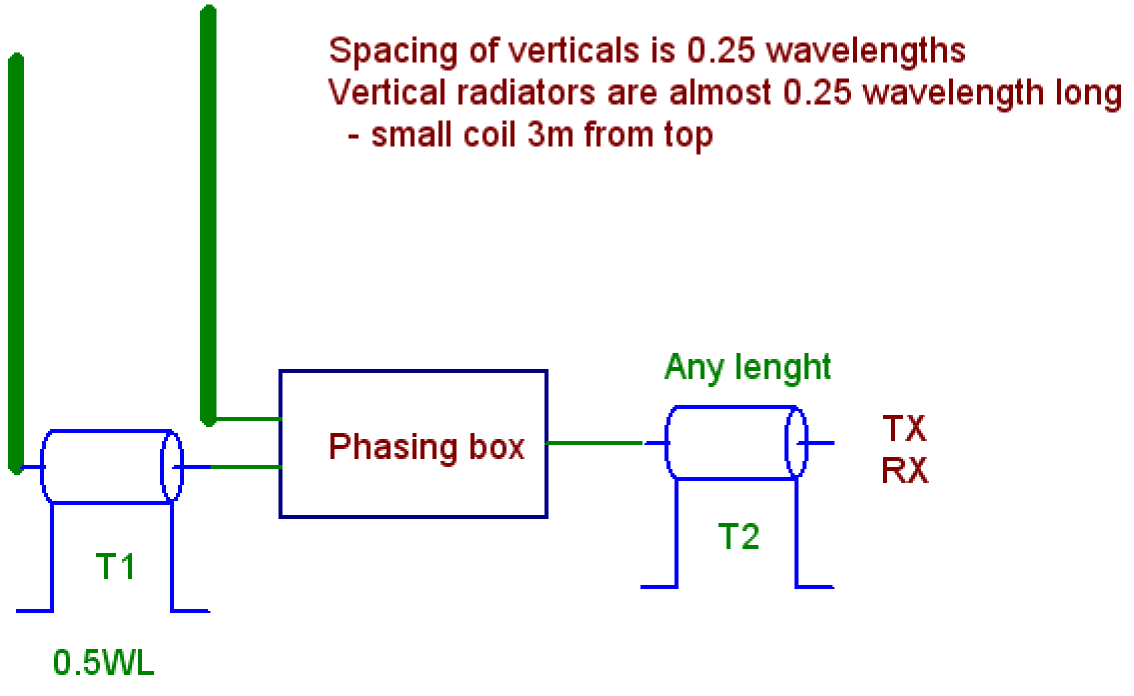


Opposite voltage fed array by OH1TV

2-element vertical array at OH1NM

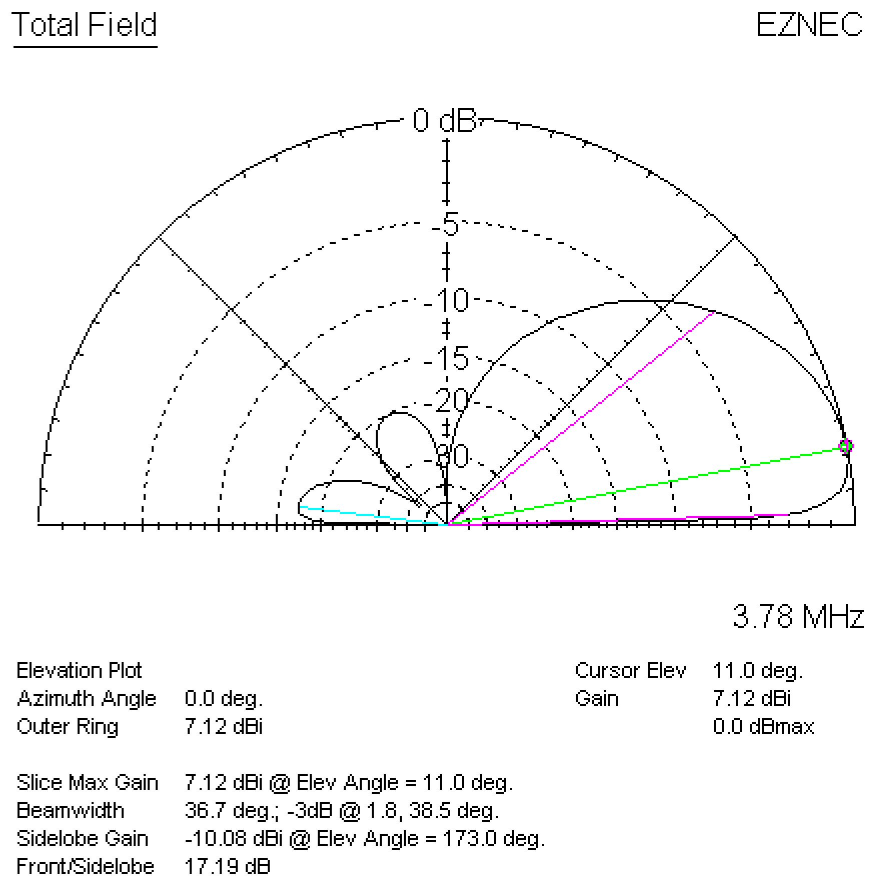
The concept

Opposite voltages fed array by OH1TV
Case: OH1NM

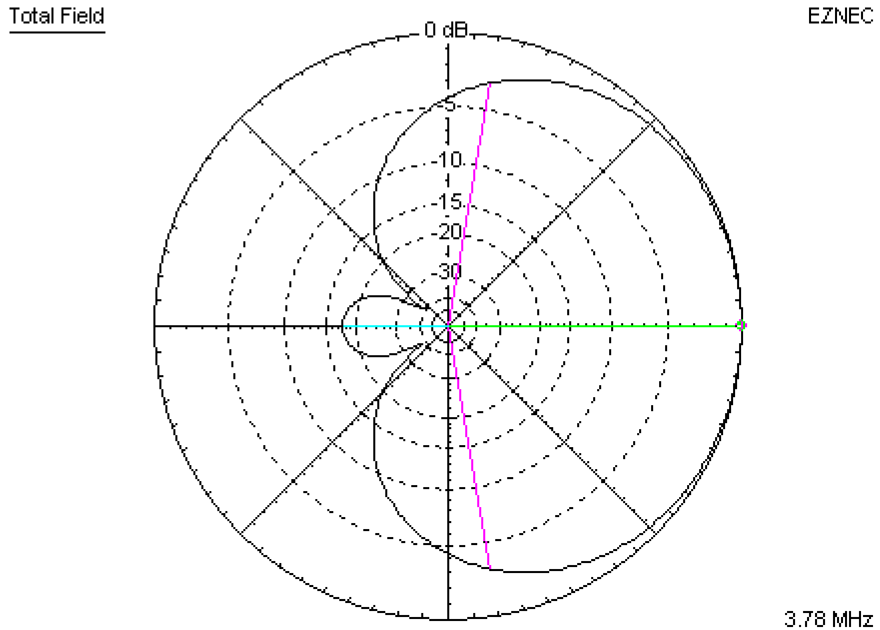


The goal

- Seaside QTH
- Elevated radials
- Phasing angle 105 degrees



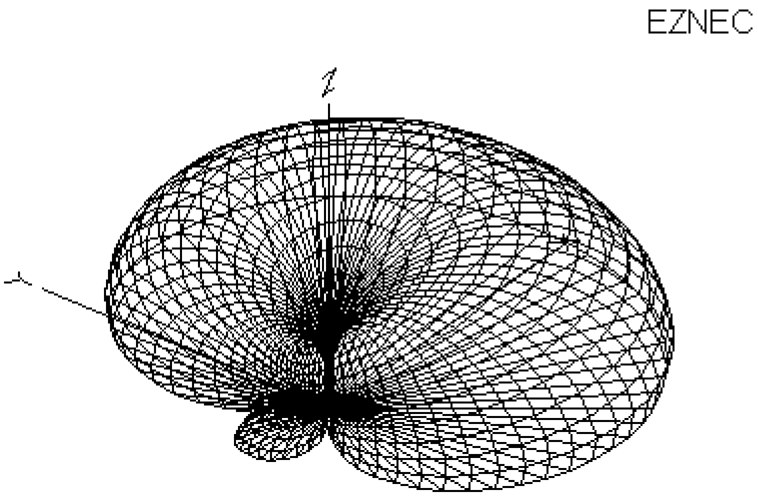
..the goal



Azimuth Plot		Cursor Az	0.0 deg.
Elevation Angle	11.0 deg.	Gain	7.12 dBi
Outer Ring	7.12 dBi		0.0 dBmax

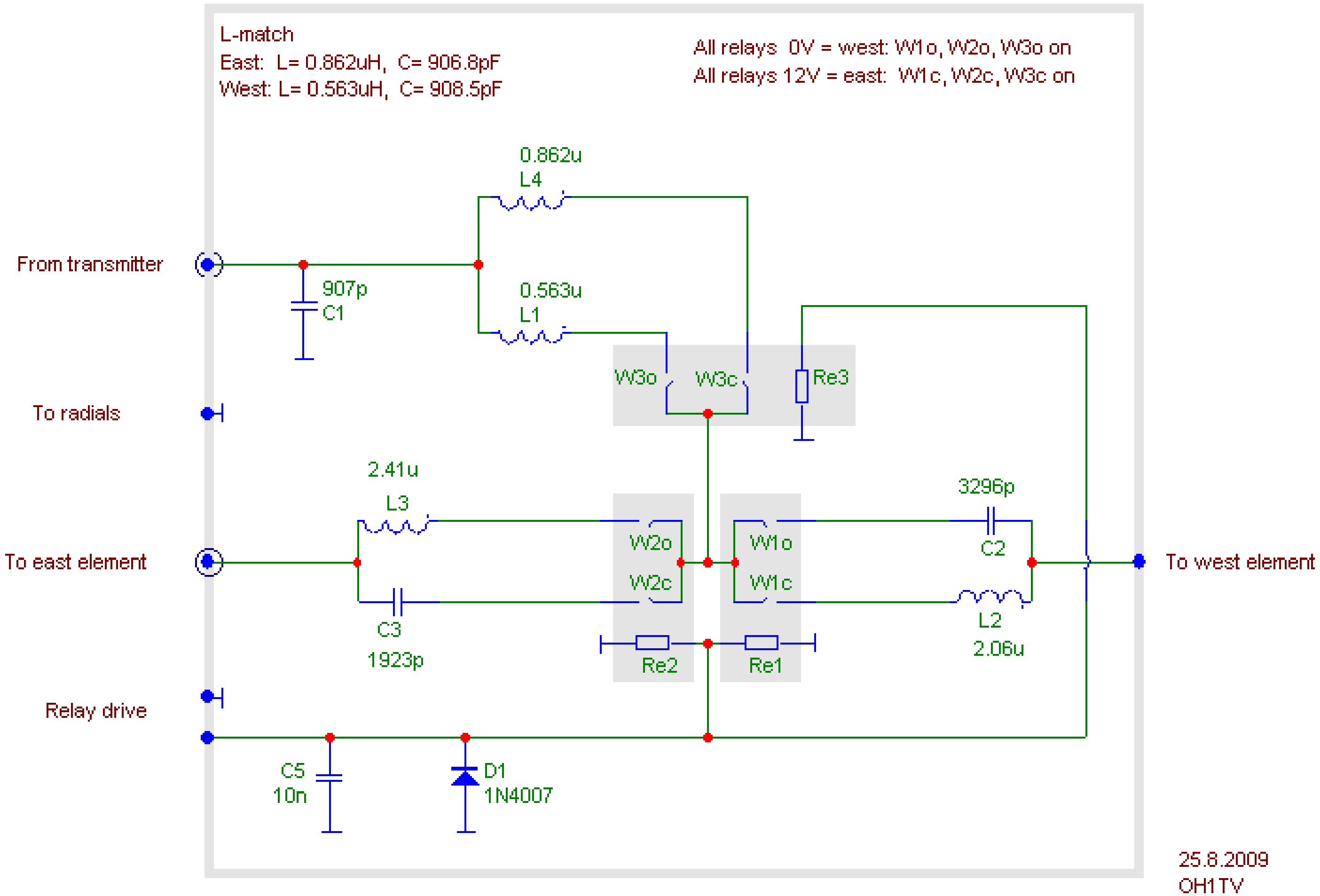
Slice Max Gain	7.12 dBi @ Az Angle = 0.0 deg.
Front/Back	17.54 dB
Beamwidth	160.6 deg.; -3dB @ 279.7, 80.3 deg.
Sidelobe Gain	-10.42 dBi @ Az Angle = 180.0 deg.
Front/Sidelobe	17.54 dB

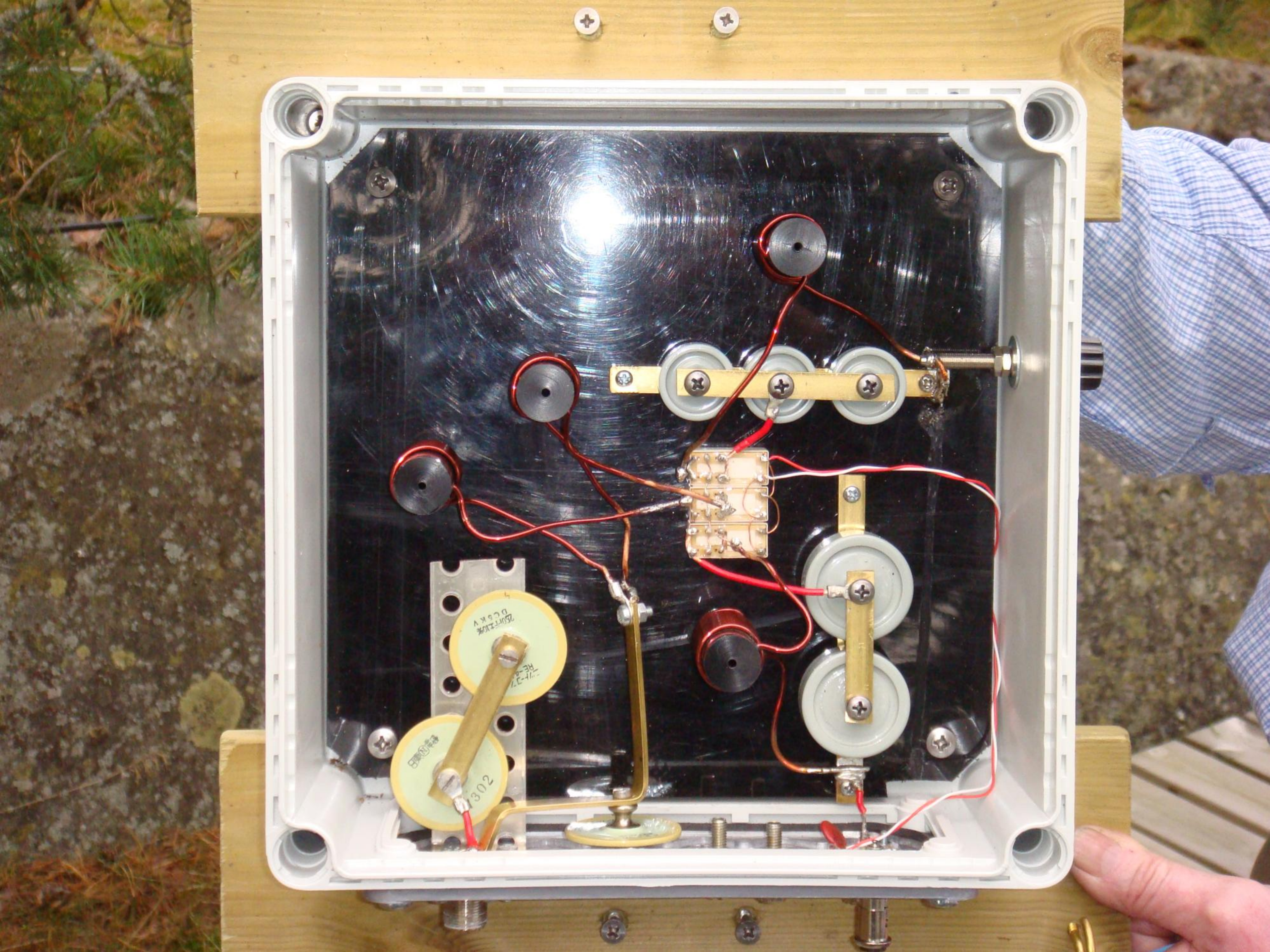
..the goal



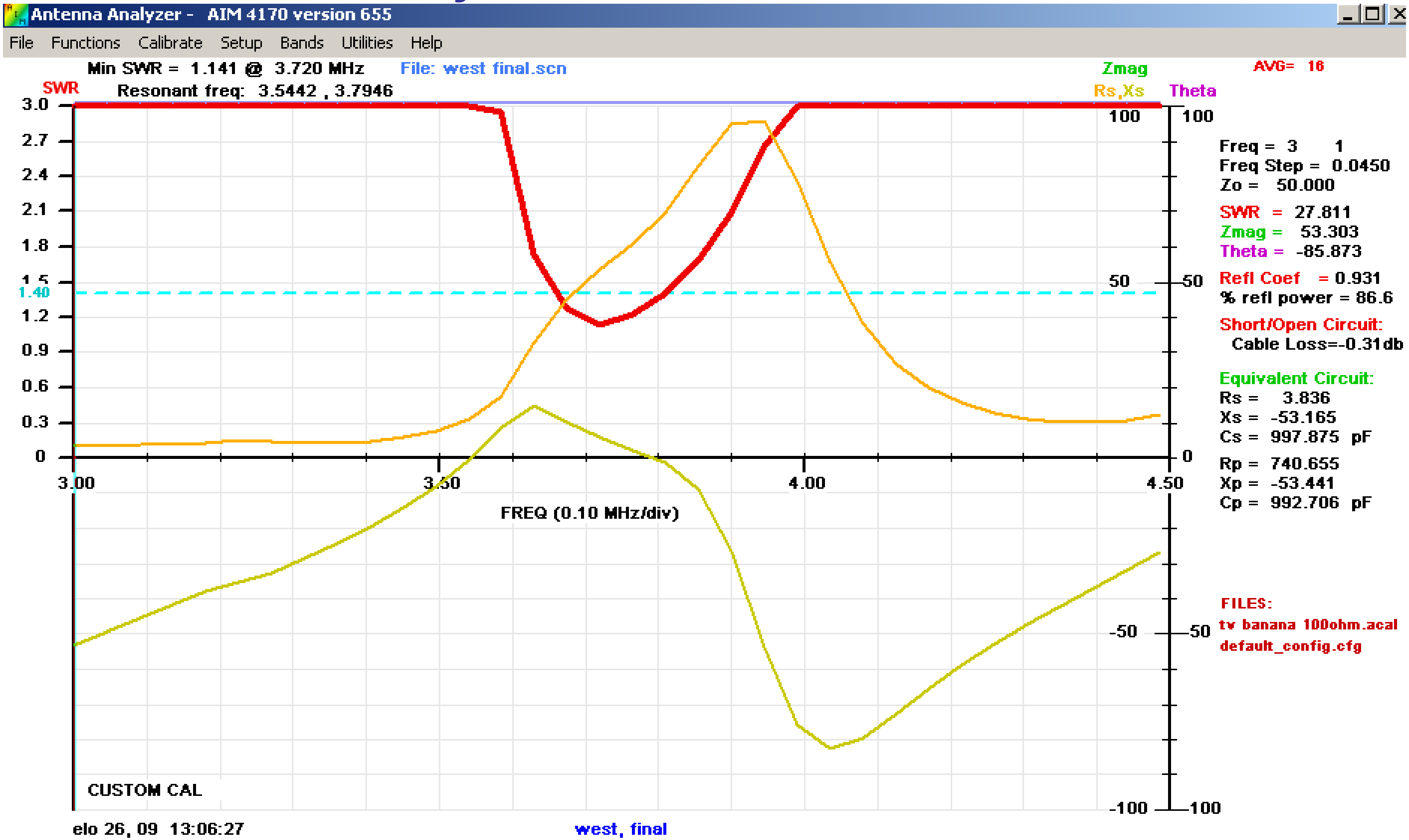
Phasing box, schematic

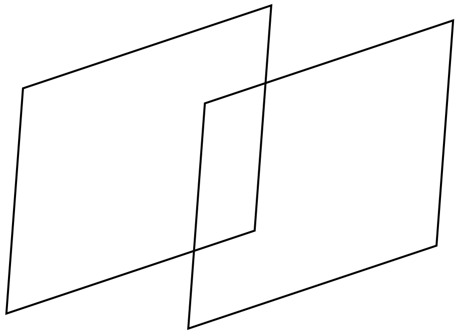
phasing angle 105 degrees





Array SWR, direction west





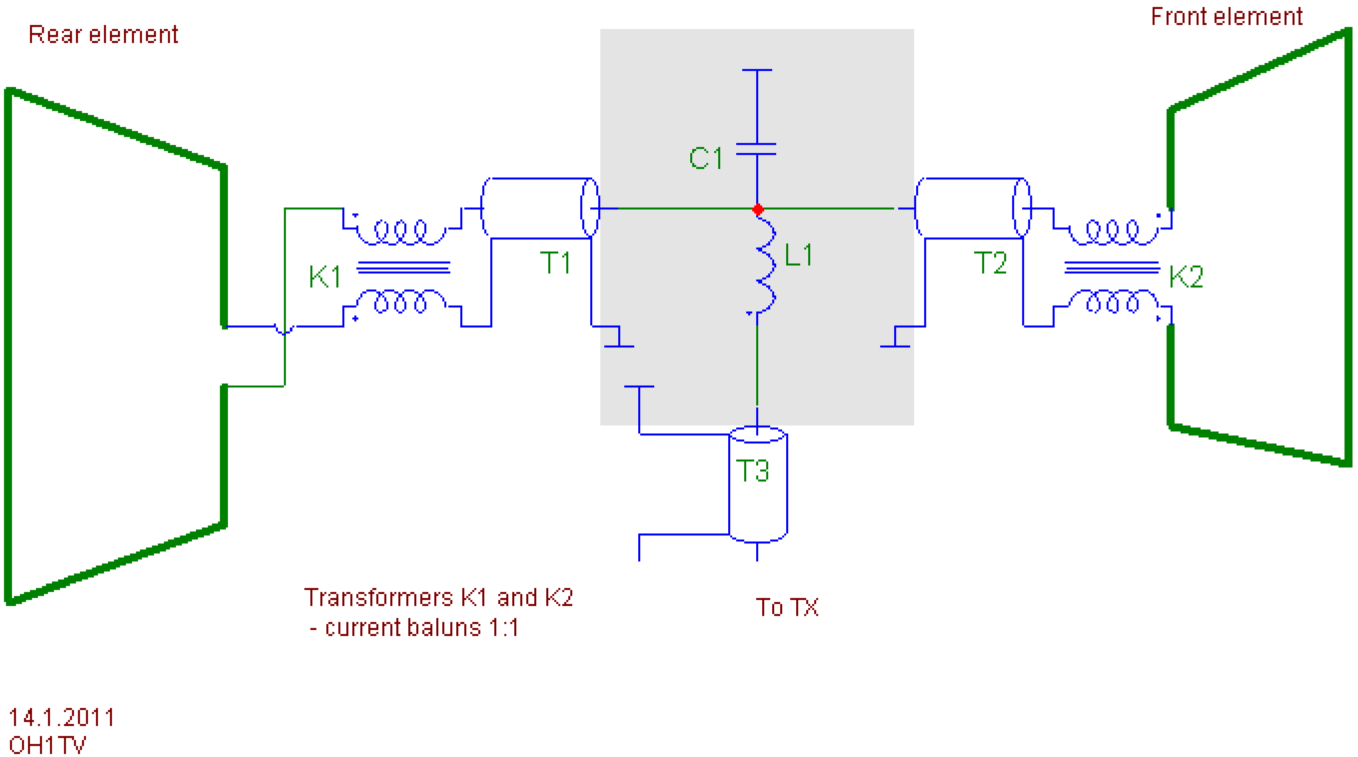
Quad improved

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



Traditional Quad on 15m

file: 2q21

Traditional

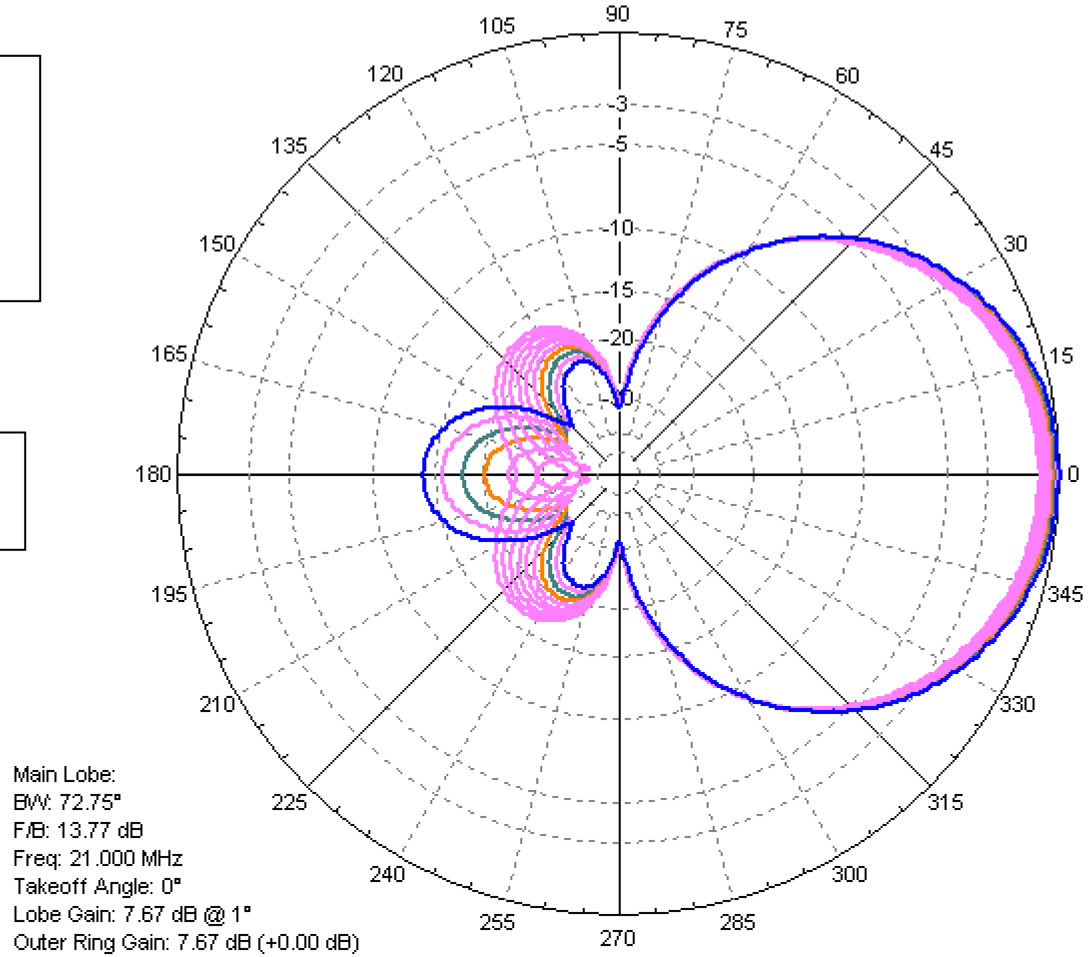
Spacing 230cm

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

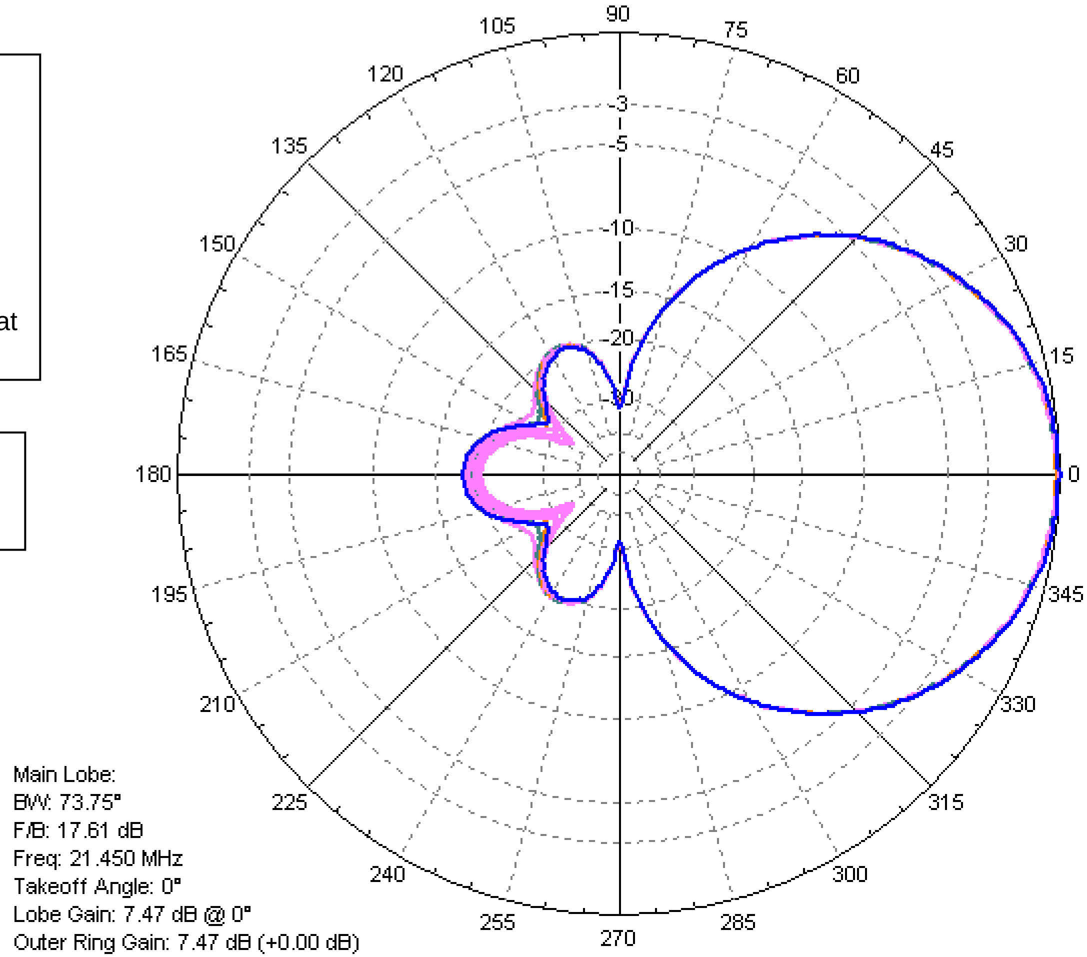
Driven 358x358cm

Reflector 376x376cm

Wire 2mm cu

Fine tuning with coils at the feedpoints

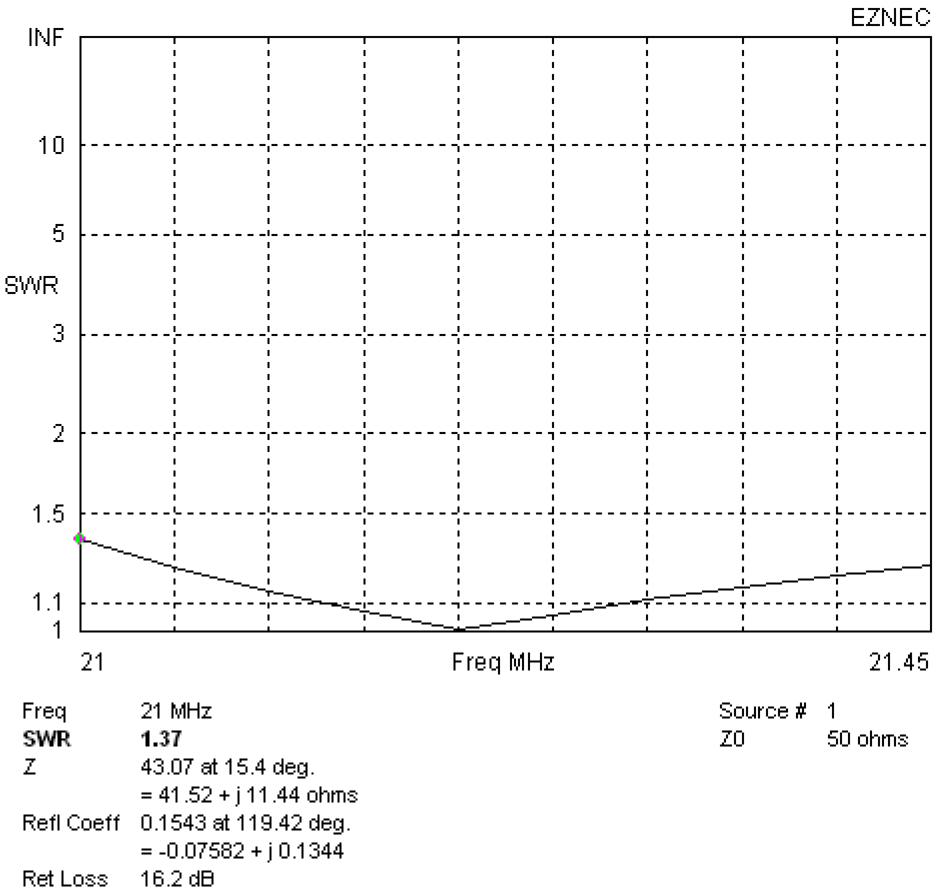
Sweep is 21.00-21.45MHz in 50kHz steps



Traditional Quad

L-match used

Sweep is 21.00-21.45MHz in 50kHz steps

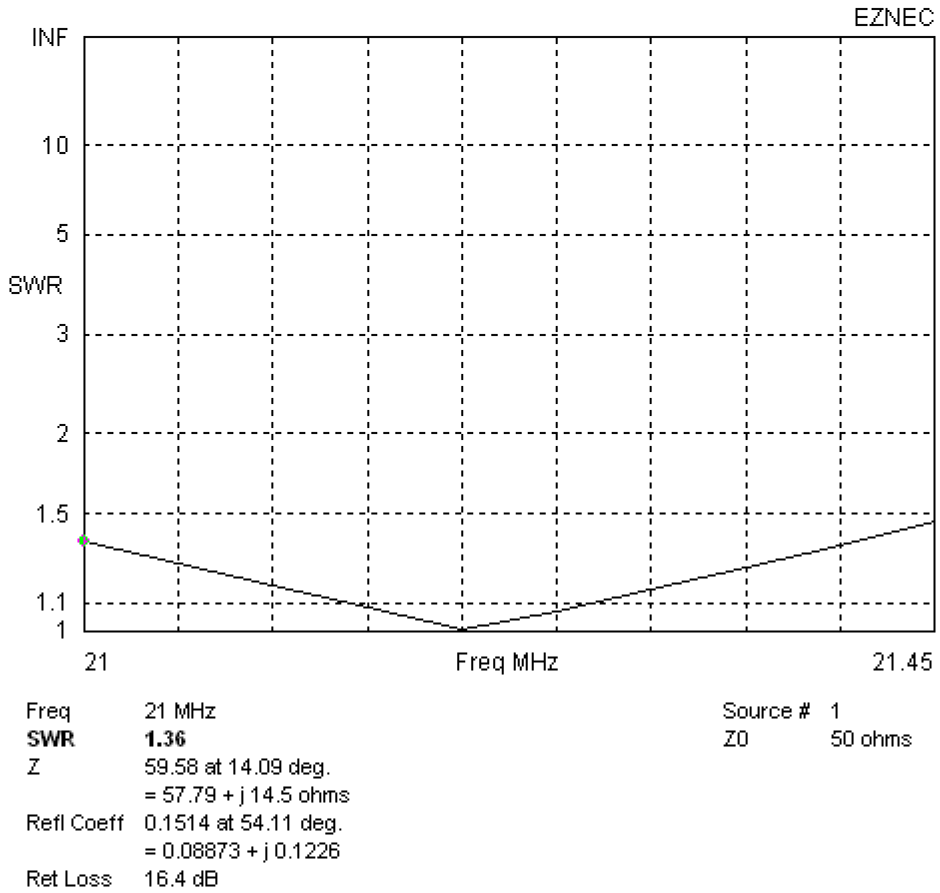


OVF-Quad

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

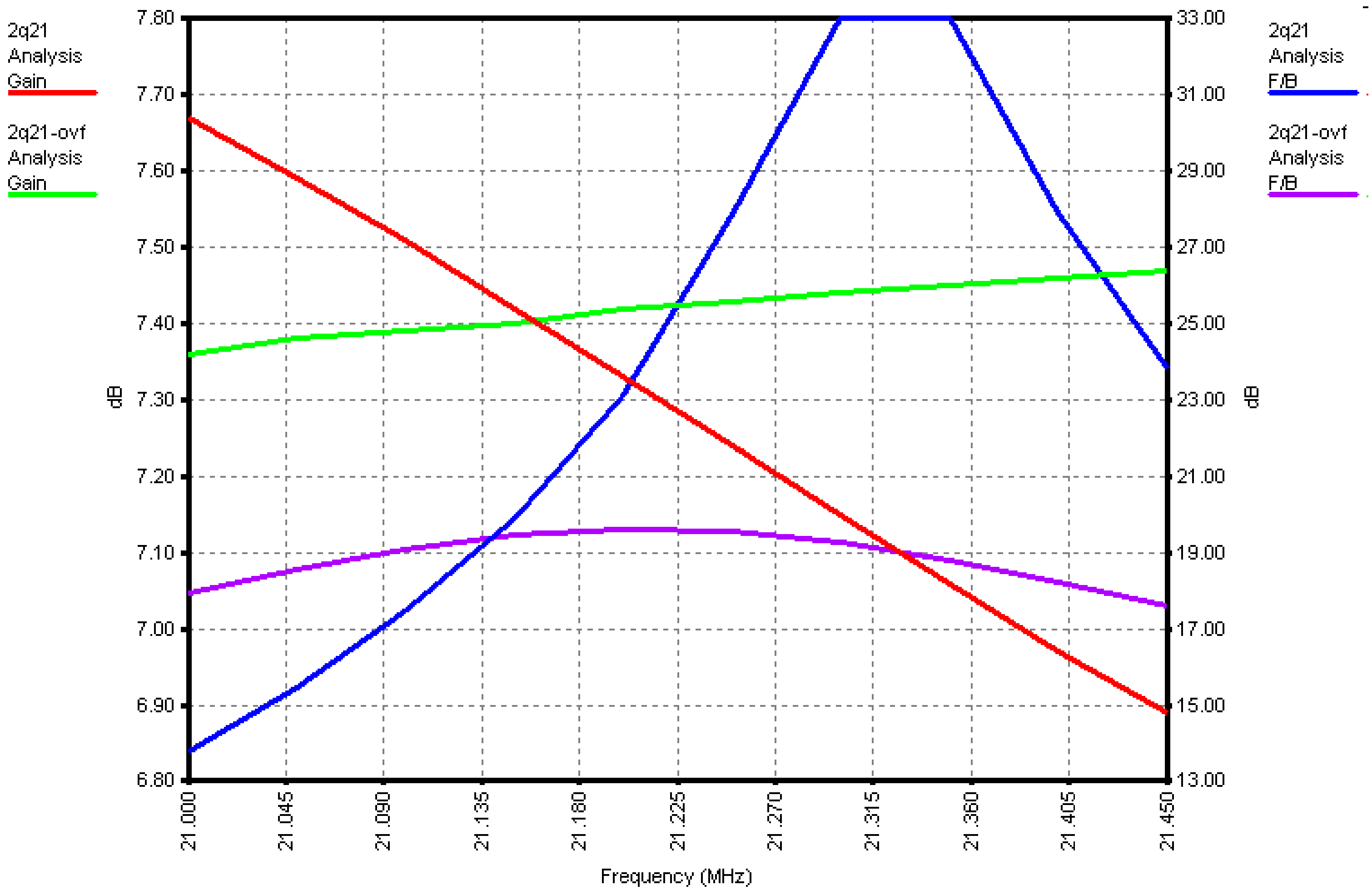
L-match used

Sweep is 21.00-21.45MHz in 50kHz steps



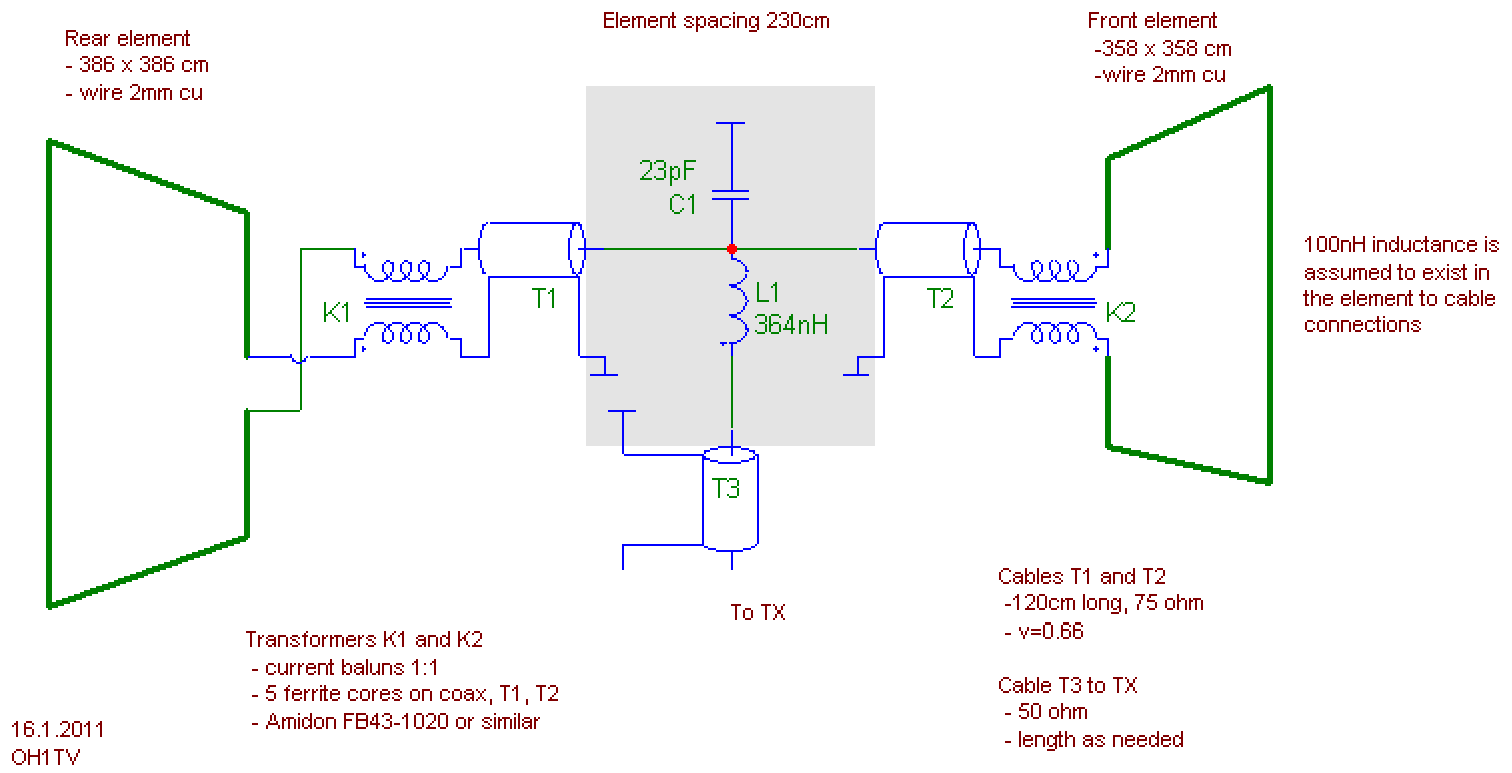
Gain and front-to-back

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



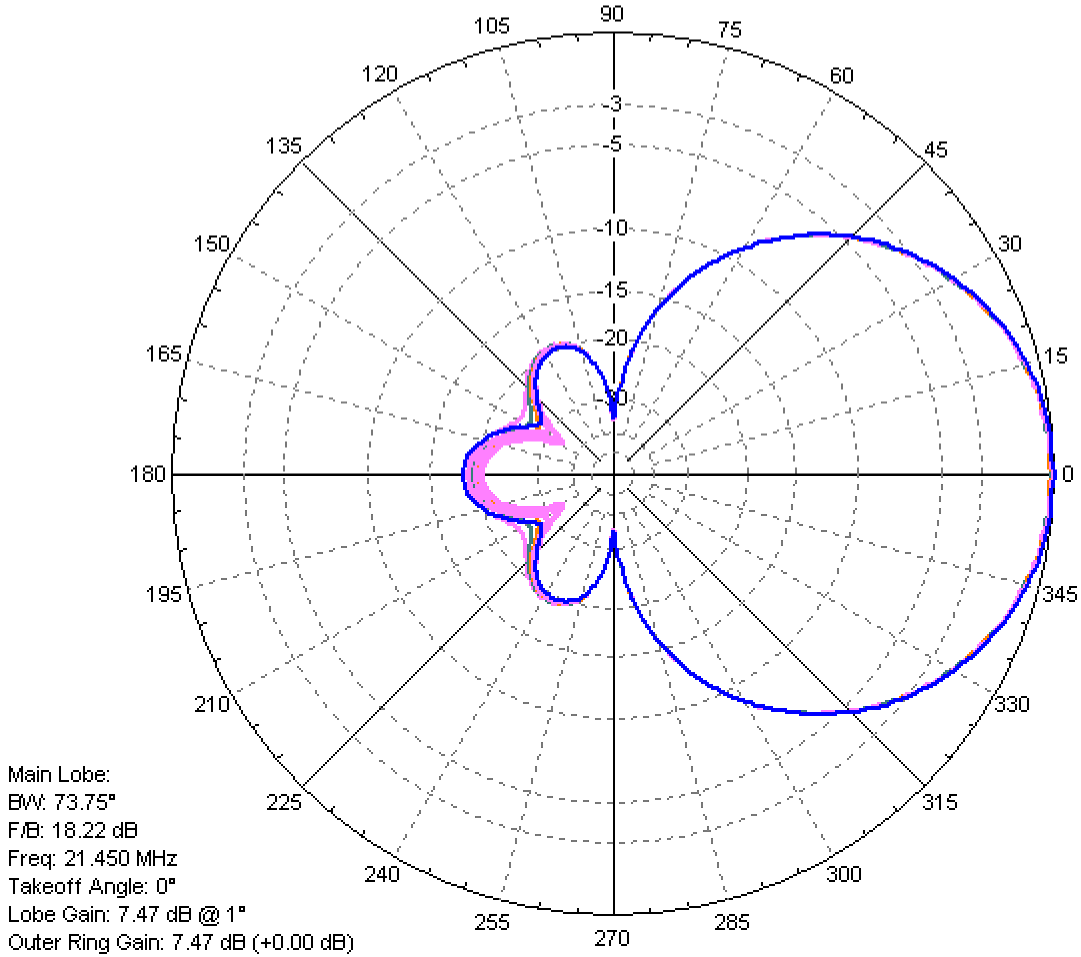
Optimized OVF-Quad

Eznec: 2q21-ovf2-75



Optimized OVF-Quad

Eznec: 2q21-ovf2-75



2q21-ovf2-75

Spacing 230cm

Driven 358x258cm

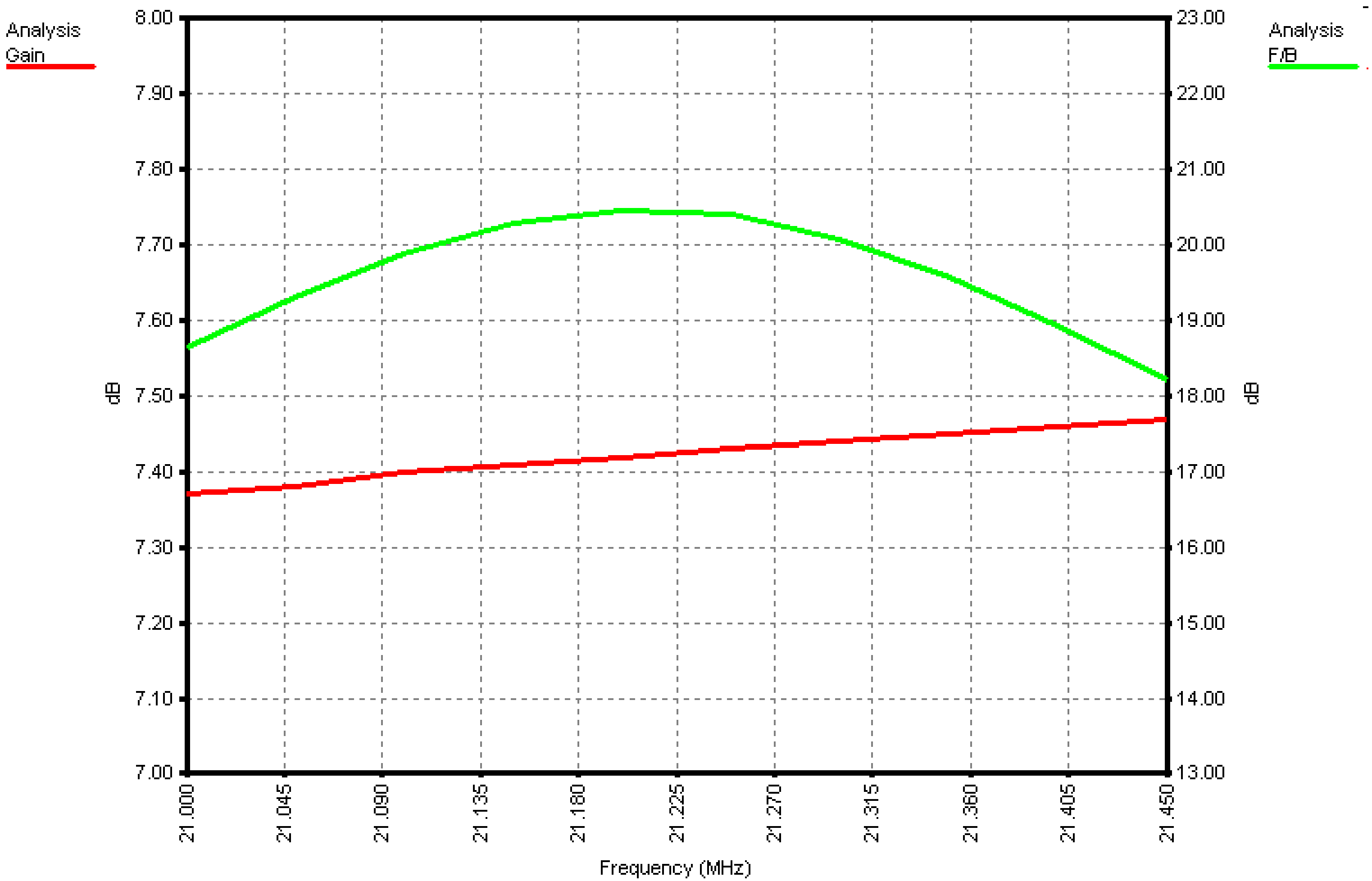
Reflector 386x386cm

Wire 2mm cu

+ 100nH coils at both feedpoints

Optimized OVF-Quad

Eznec: 2q21-ovf2-75

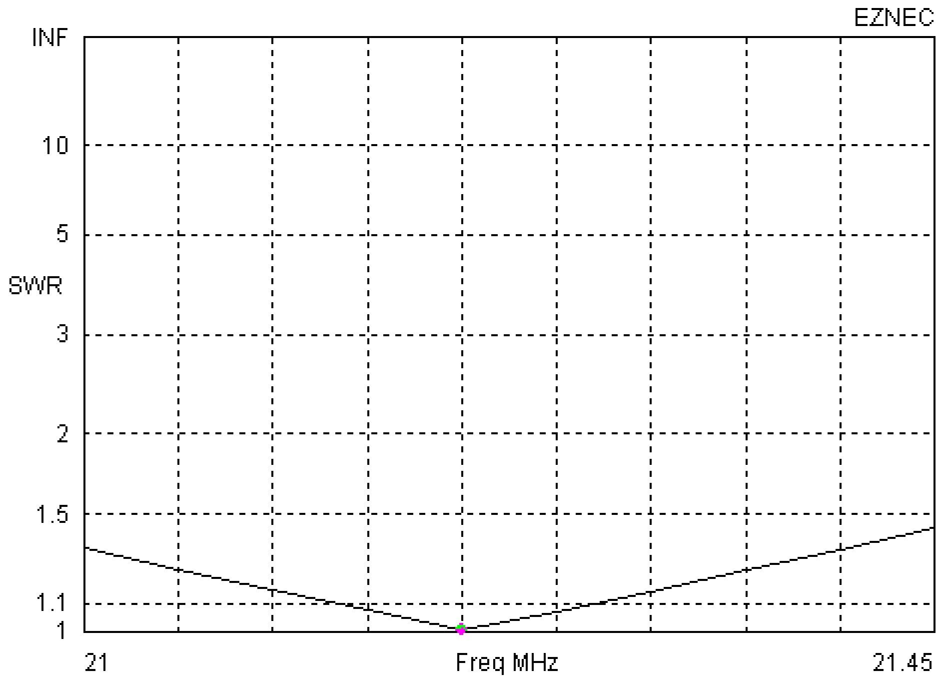


Optimized OVF-Quad

2q21-ovf2-75

L-match used

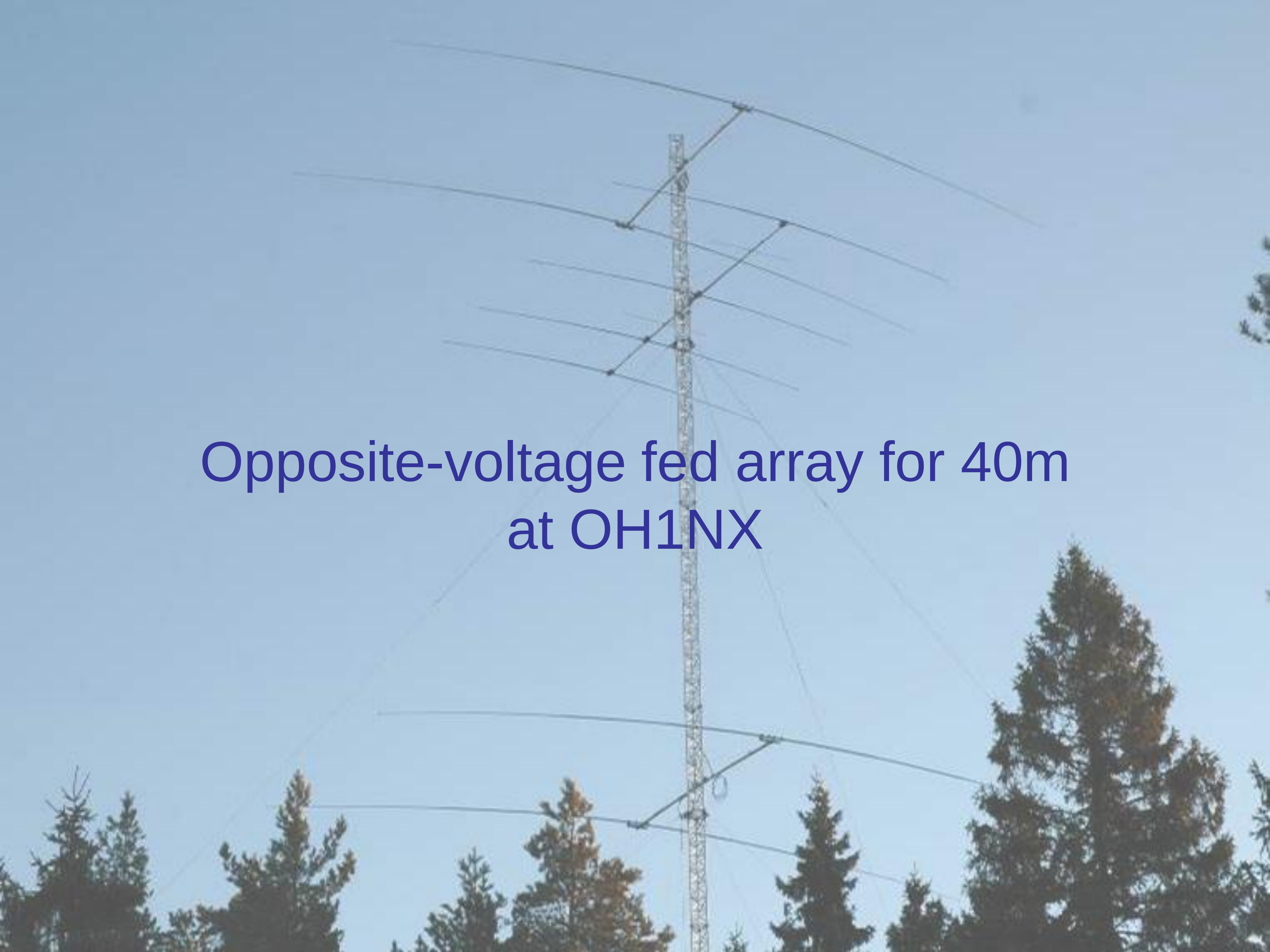
Sweep is 21.00-21.45MHz in 50kHz steps



Freq	21.2 MHz	Source #	1
SWR	**1.006**	Z0	50 ohms
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		

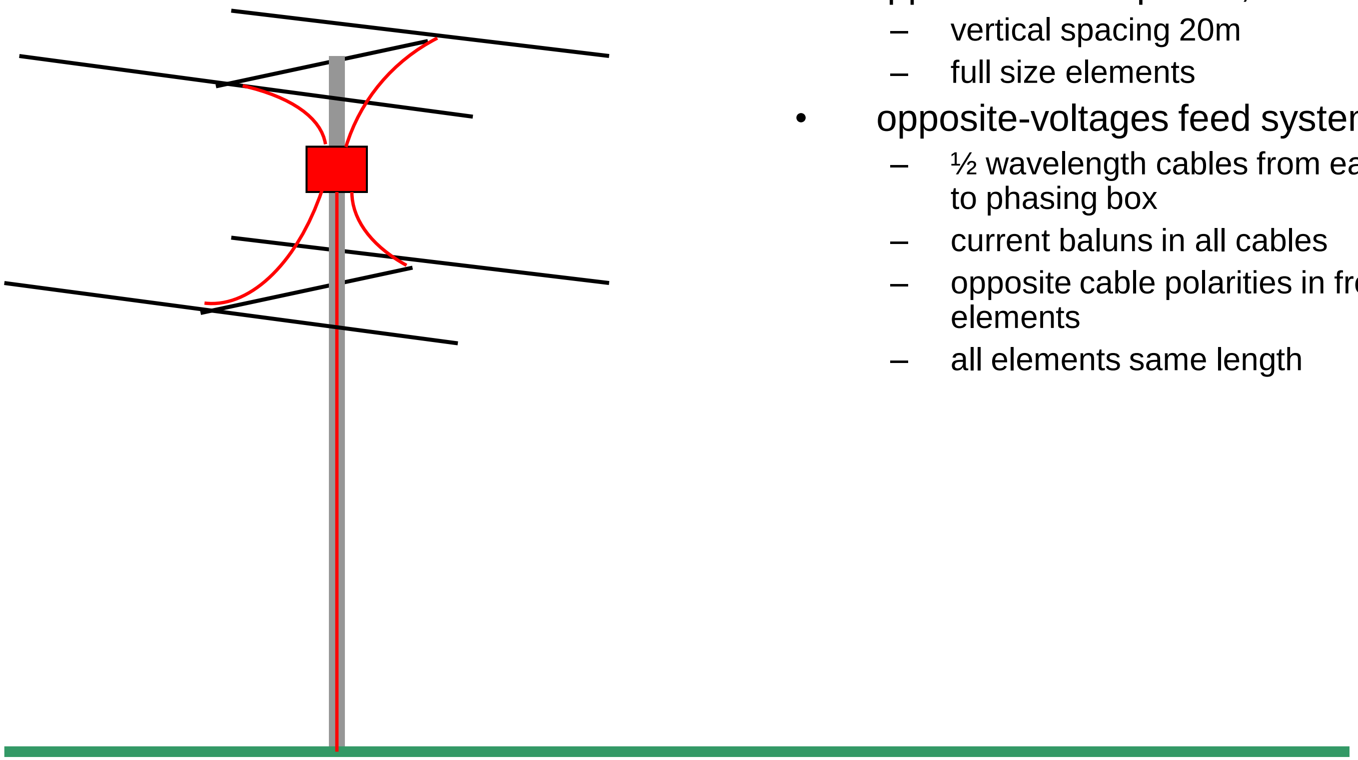
Conclusions

- <u>Opposite voltage feed makes 2-el Quad less frequency dependent</u>
    - 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

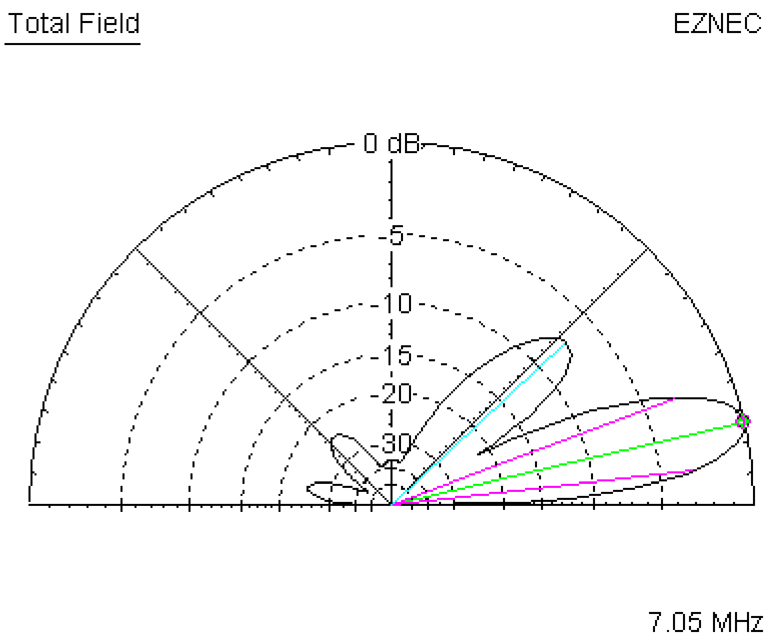


- upper antenna up 49m, lower ant 29m
  - vertical spacing 20m
  - full size elements
- opposite-voltages feed system
  - ½ wavelength cables from each element to phasing box
  - current baluns in all cables
  - opposite cable polarities in front and rear elements
  - all elements same length

Features

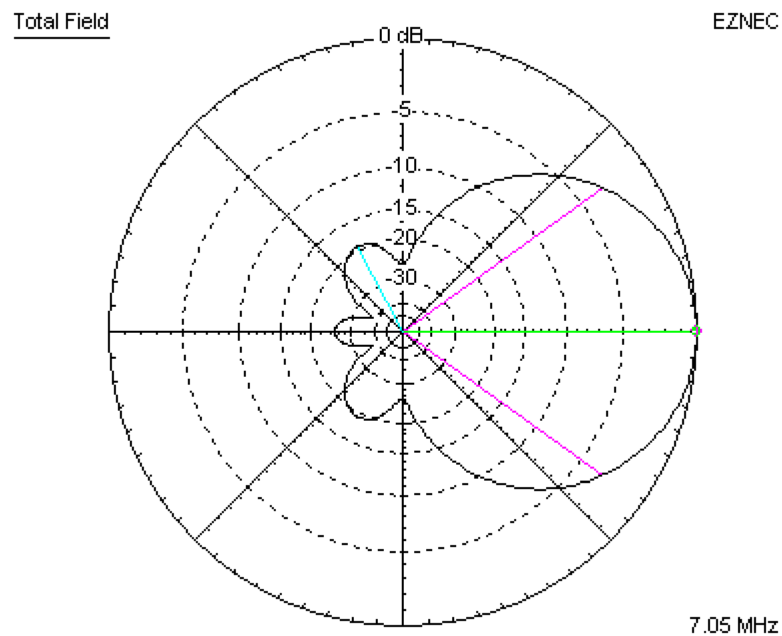
- Good F/B over the whole band
  - Equal current amplitudes in all elements
  - Low vertical side lobes in DX-position because of stacking
  - Two frequency settings, 7000-7100 and 7100-7200kHz
    - Both settings cover the whole 40m band quite well
- Wideband (less so in the local position)
- Switchable 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



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

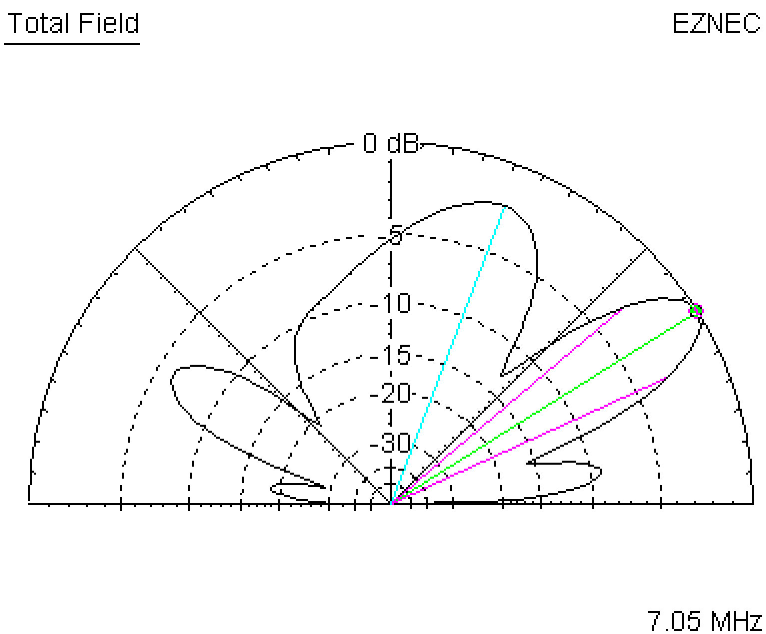


Azimuth Plot		Cursor Az	0.0 deg.
Elevation Angle	13.0 deg.	Gain	14.06 dBi
Outer Ring	14.06 dBi		0.0 dBmax

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

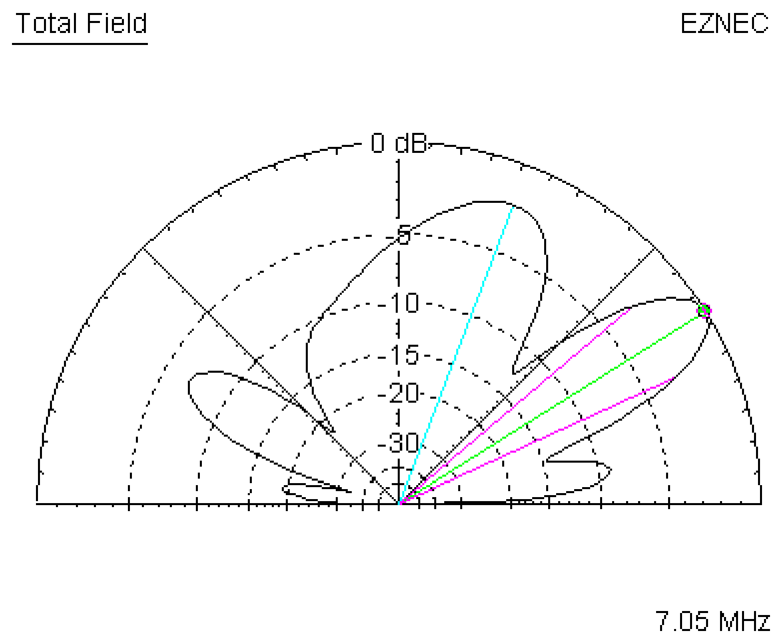
Position Local, 32deg TOA

7050kHz | 7150kHz



Elevation Plot		Cursor Elev	32.0 deg.
Azimuth Angle	0.0 deg.	Gain	11.13 dBi
Outer Ring	11.13 dBi		0.0 dBmax

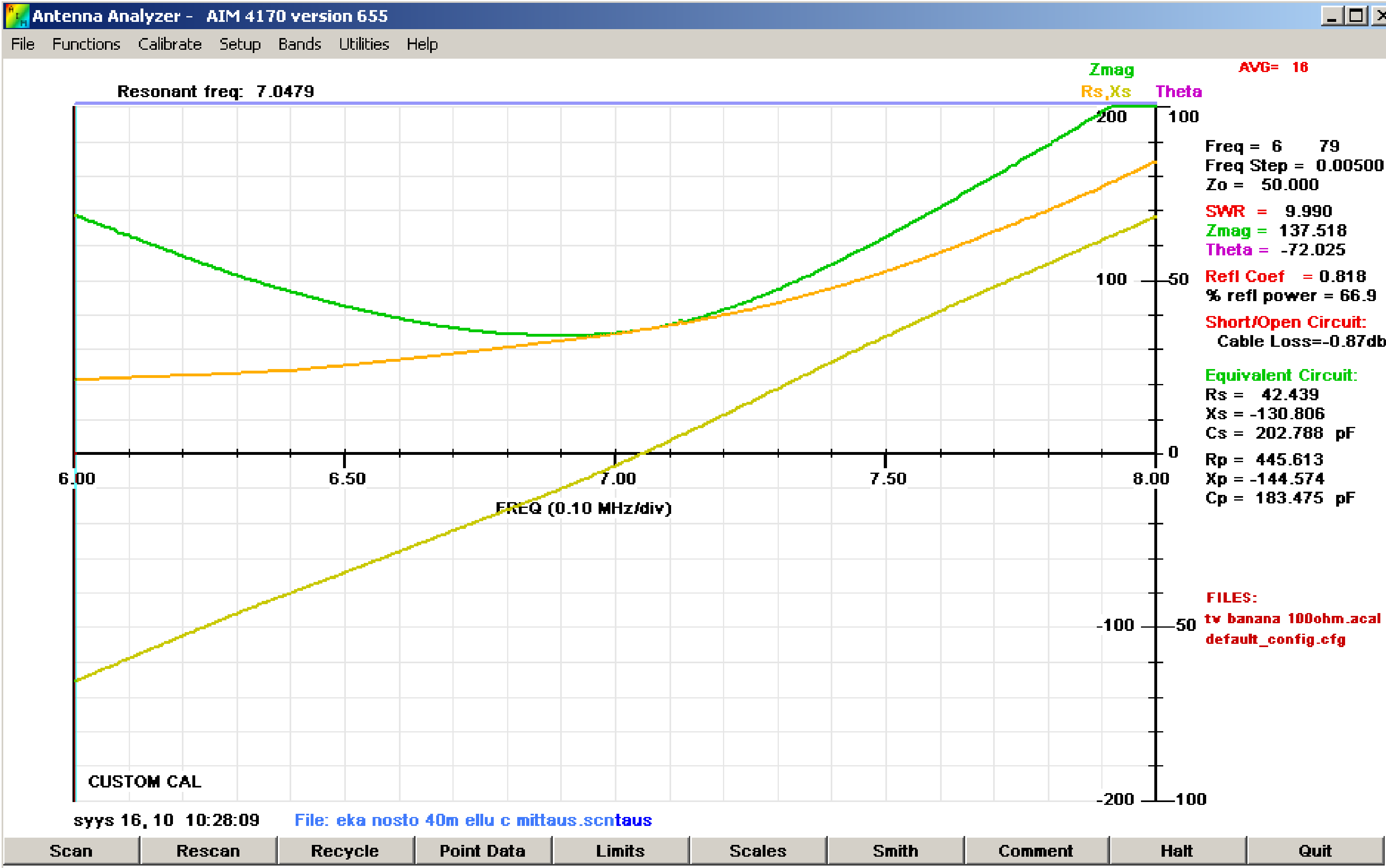
Slice Max Gain 11.13 dBi @ Elev Angle = 32.0 deg.
Beamwidth 15.7 deg.; -3dB @ 24.6, 40.3 deg.
Sidelobe Gain 8.97 dBi @ Elev Angle = 69.0 deg.
Front/Sidelobe 2.17 dB



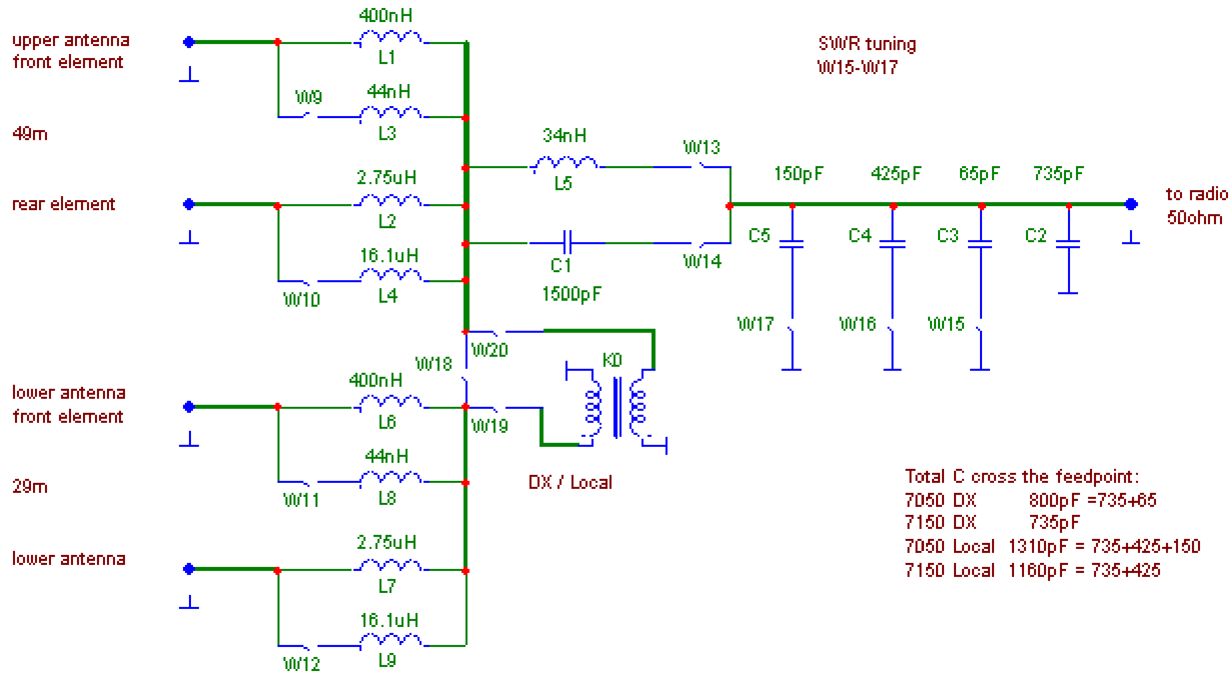
Elevation Plot		Cursor Elev	32.0 deg.
Azimuth Angle	0.0 deg.	Gain	11.19 dBi
Outer Ring	11.19 dBi		0.0 dBmax

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 lamda/2 on 7046.6kHz



Total C cross the feedpoint:
7050 DX 800pF =735+65
7150 DX 735pF
7050 Local 1310pF = 735+425+150
7150 Local 1160pF = 735+425

DX: W18 is on, but W19, W20 are offi
Local: W19, W20 are on, but W18 is off

7050kHz: relays W9,W10, W11, W12 are off
7150kHz: W9, W10, W11, W12 are on

DX: W13 is on
Local: W14 is on

V4c
2.1.2011
OH1TV