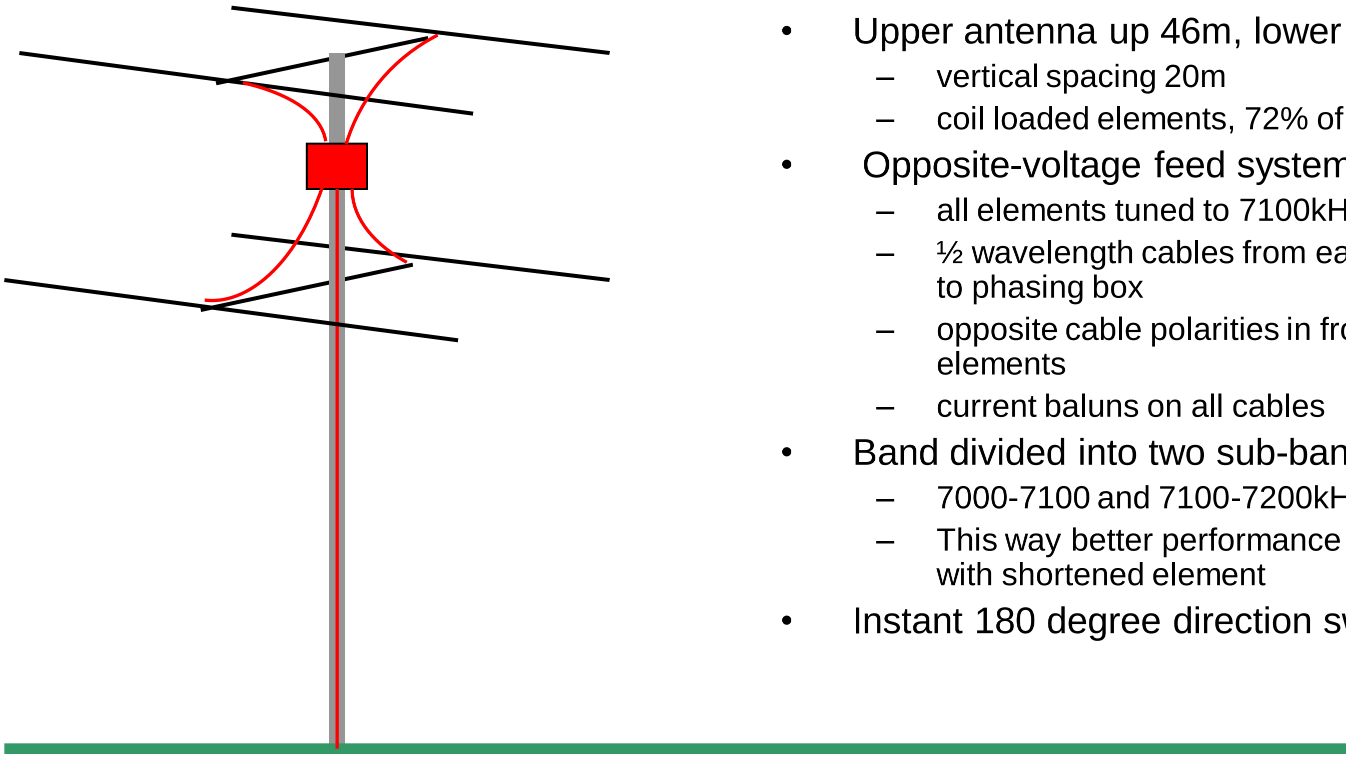
2 o 2 phased array for 40m at OH2BH

This 40m antenna was designed for OH2BH to replace a storm destroyed earlier antenna.

Design goals were compact size, good in transmitting and receiving and agile in contest

OH1TV

2 over 2 phased array for 40m



- Upper antenna up 46m, lower ant 26m
  - vertical spacing 20m
  - coil loaded elements, 72% of full size
- Opposite-voltage feed system
  - all elements tuned to 7100kHz
  - ½ wavelength cables from each element to phasing box
  - opposite cable polarities in front and rear elements
  - current baluns on all cables
- Band divided into two sub-bands
  - 7000-7100 and 7100-7200kHz
  - This way better performance is achieved with shortened element
- Instant 180 degree direction switching

Features

- Shortened elements, 15m @ 40m band
  - Makes stacking easier, the antenna below guy wires can be higher
  - Lower stress to the tower, lower wind and ice load
- Good F/B over the whole band, important on 40m receiving
  - Low vertical side lobes because of 0.5lamda stacking
  - Two frequency settings, 7000-7100 and 7100-7200kHz
  - Equal current amplitudes in all elements
- Instant 180deg direction switching
  - Often needed in contest on 40m

What is Opposite Voltage Feed?

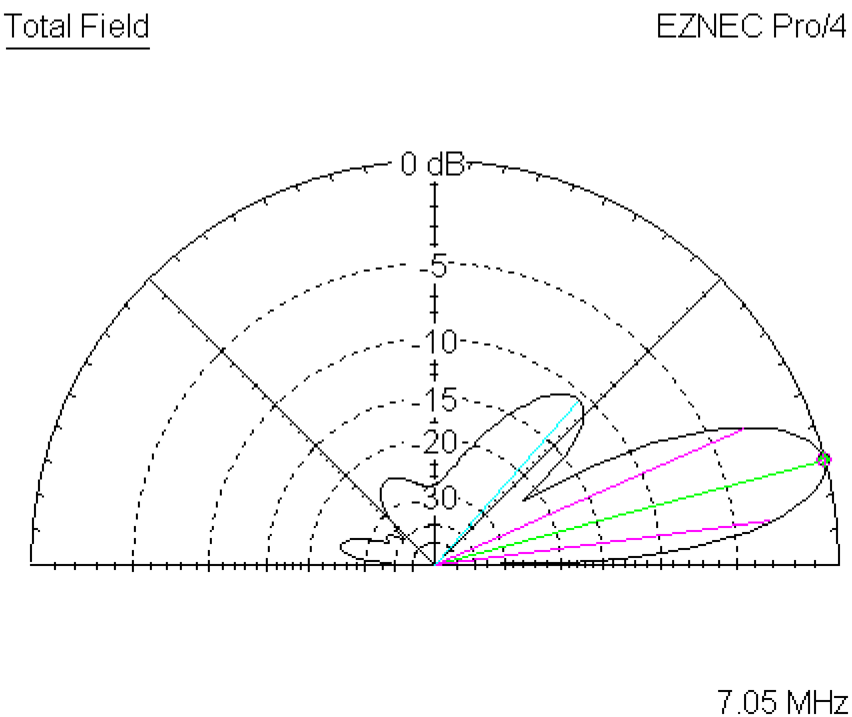
OVF is a method to feed 2-element antennas. It makes possible to adjust current amplitudes and phases so that good radiation pattern can be achieved. The main advantage is insensitivity of radiation pattern to frequency change. The concept is that equal amplitude but opposite phase voltages are brought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

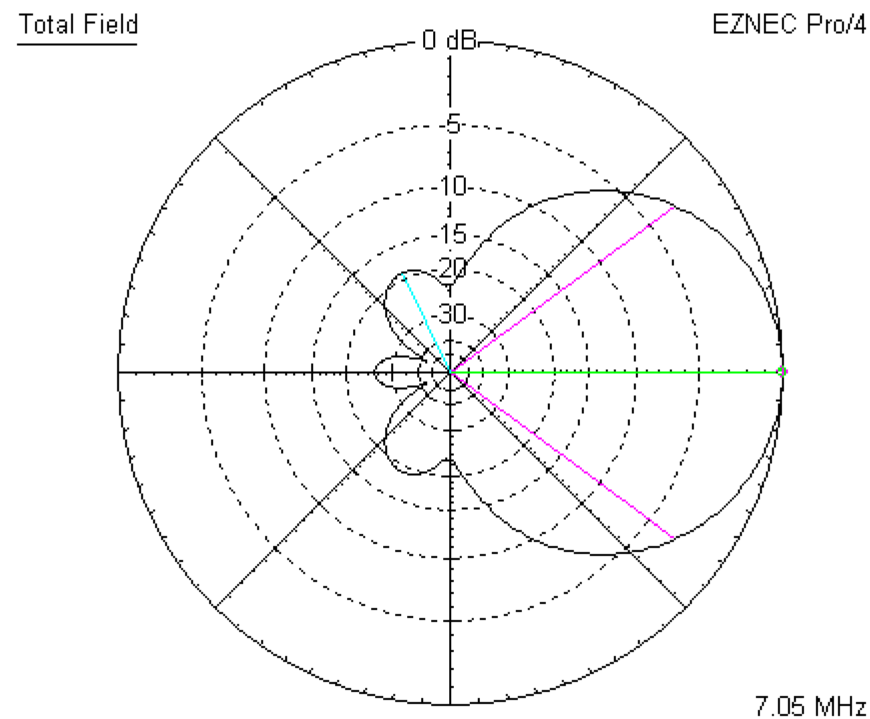
Opposite phase normally is generated with half wavelength cable. It can be achieved also with cable polarity inversion and two cables, each half wavelength long.

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.

Modeled performance

7050kHz pattern, sub-band center





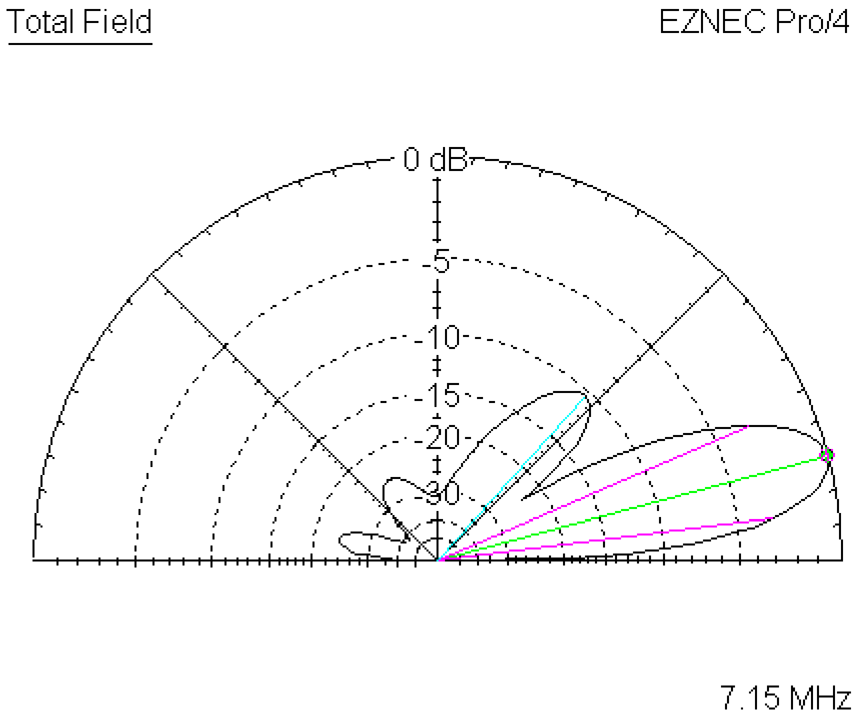
Elevation Plot		Cursor Elev	15.0 deg.
Azimuth Angle	0.0 deg.	Gain	13.29 dBi
Outer Ring	13.29 dBi		0.0 dBmax

Slice Max Gain	13.29 dBi @ Elev Angle = 15.0 deg.
Beamwidth	16.5 deg.; -3dB @ 7.3, 23.8 deg.
Sidelobe Gain	2.76 dBi @ Elev Angle = 49.0 deg.
Front/Sidelobe	10.53 dB

Azimuth Plot		Cursor Az	0.0 deg.
Elevation Angle	15.0 deg.	Gain	13.29 dBi
Outer Ring	13.29 dBi		0.0 dBmax

Slice Max Gain	13.29 dBi @ Az Angle = 0.0 deg.
Front/Back	25.43 dB
Beamwidth	73.5 deg.; -3dB @ 323.2, 36.7 deg.
Sidelobe Gain	-5.6 dBi @ Az Angle = 116.0 deg.
Front/Sidelobe	18.89 dB

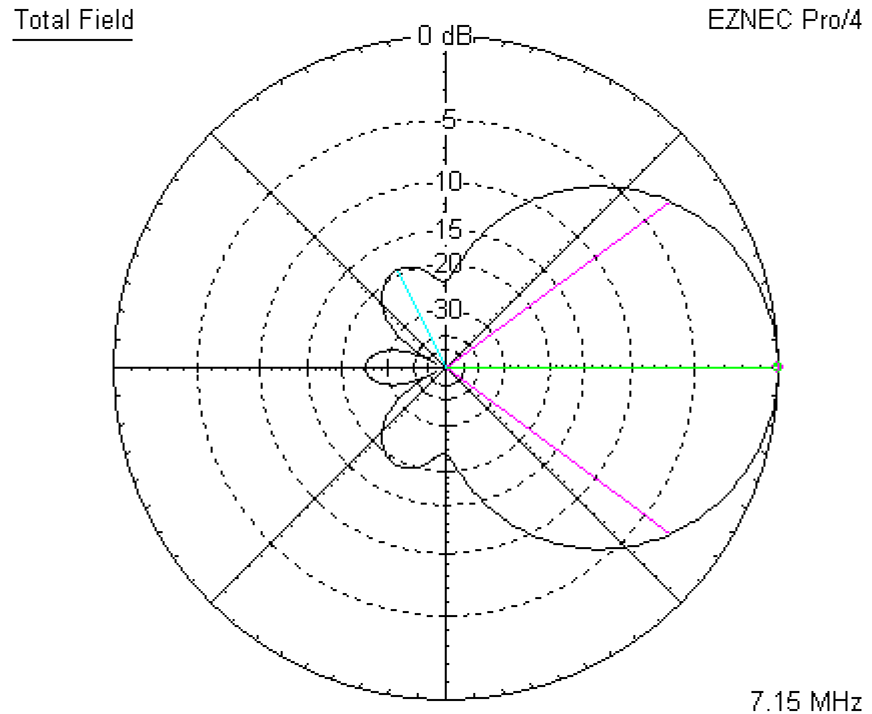
7150kHz pattern, sub-band center



Elevation Plot
Azimuth Angle 0.0 deg.
Outer Ring 13.38 dBi

Cursor Elev 15.0 deg.
Gain 13.38 dBi
0.0 dBmax

Slice Max Gain 13.38 dBi @ Elev Angle = 15.0 deg.
Beamwidth 16.2 deg.; -3dB @ 7.2, 23.4 deg.
Sidelobe Gain 2.97 dBi @ Elev Angle = 48.0 deg.
Front/Sidelobe 10.41 dB

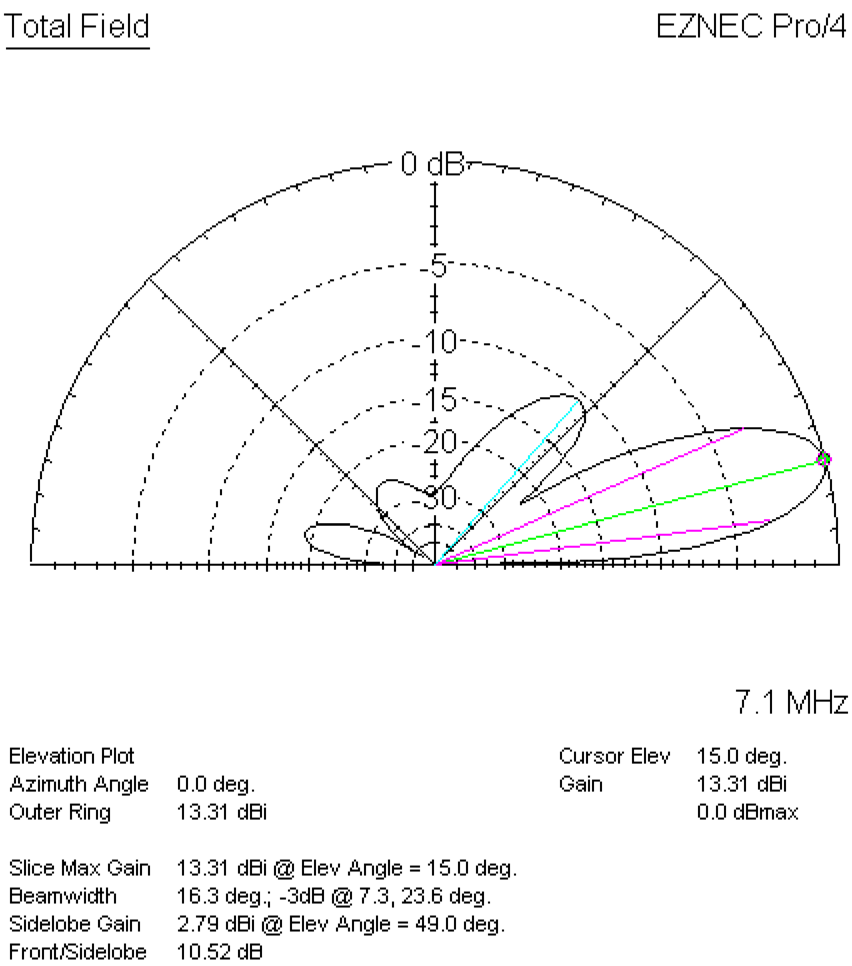


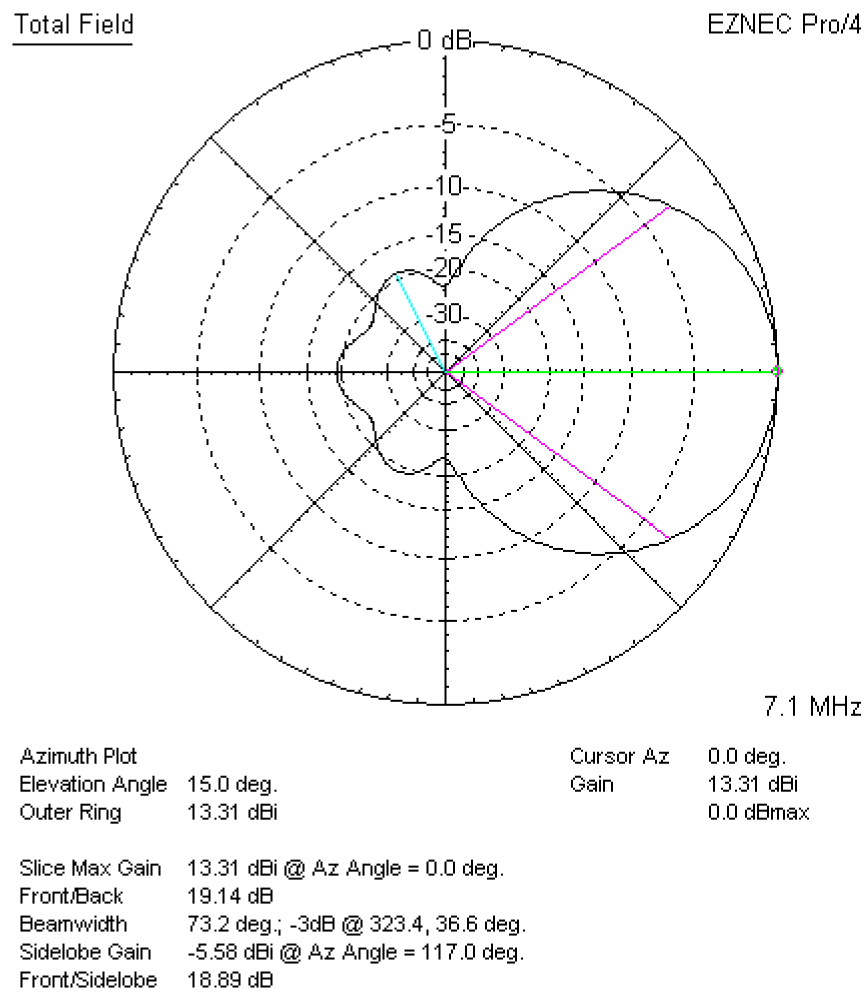
Azimuth Plot
Elevation Angle 15.0 deg.
Outer Ring 13.38 dBi

Cursor Az 0.0 deg.
Gain 13.38 dBi
0.0 dBmax

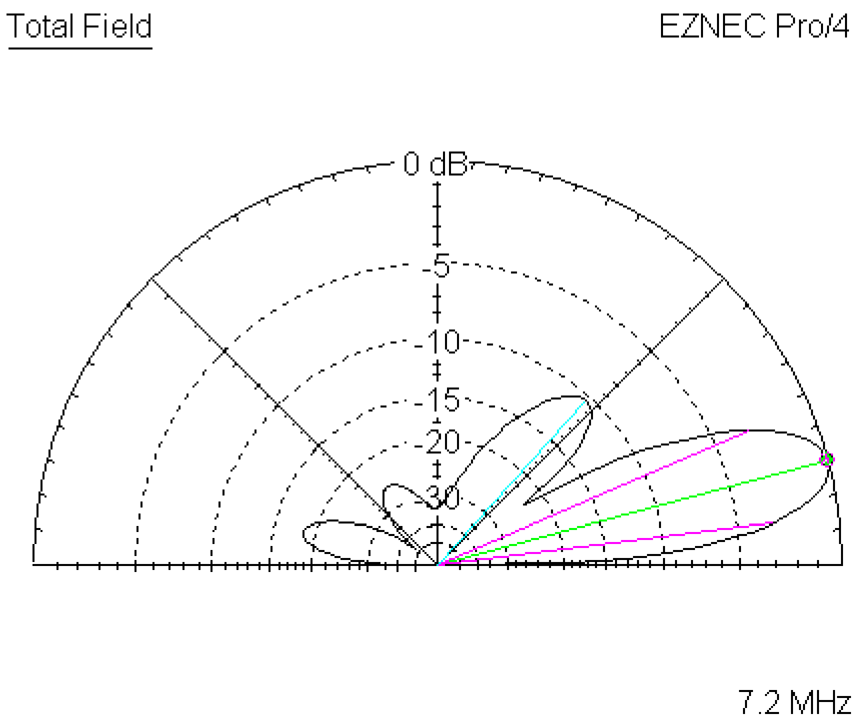
Slice Max Gain 13.38 dBi @ Az Angle = 0.0 deg.
Front/Back 24.42 dB
Beamwidth 73.2 deg.; -3dB @ 323.4, 36.6 deg.
Sidelobe Gain -5.69 dBi @ Az Angle = 116.0 deg.
Front/Sidelobe 19.07 dB

7100kHz pattern, sub-band low end





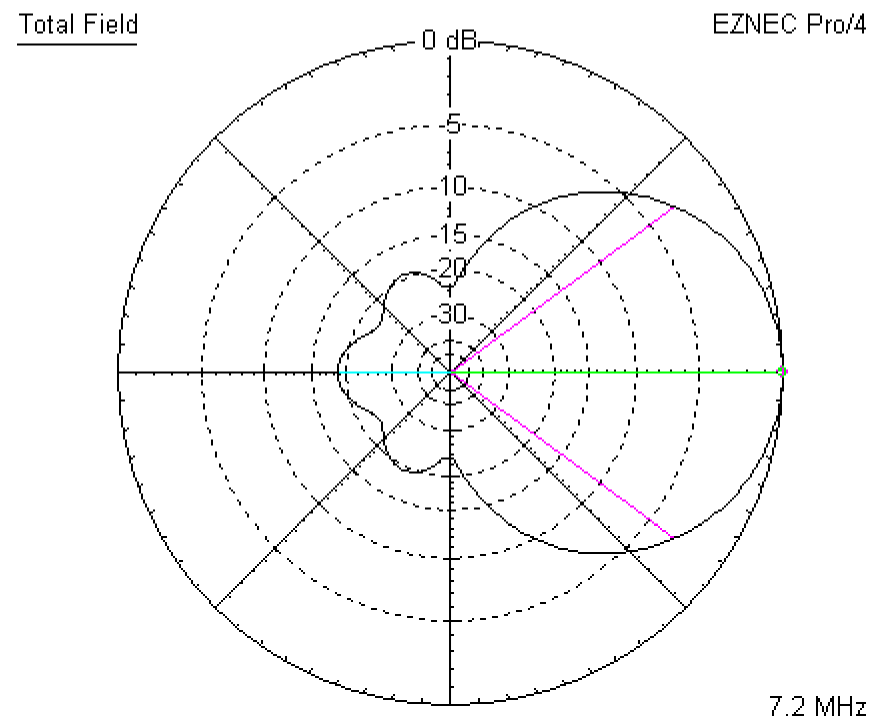
7200kHz pattern, sub-band high end



Elevation Plot
Azimuth Angle 0.0 deg.
Outer Ring 13.37 dBi

Cursor Elev 15.0 deg.
Gain 13.37 dBi
0.0 dBmax

Slice Max Gain 13.37 dBi @ Elev Angle = 15.0 deg.
Beamwidth 16.0 deg.; -3dB @ 7.2, 23.2 deg.
Sidelobe Gain 3.02 dBi @ Elev Angle = 48.0 deg.
Front/Sidelobe 10.35 dB

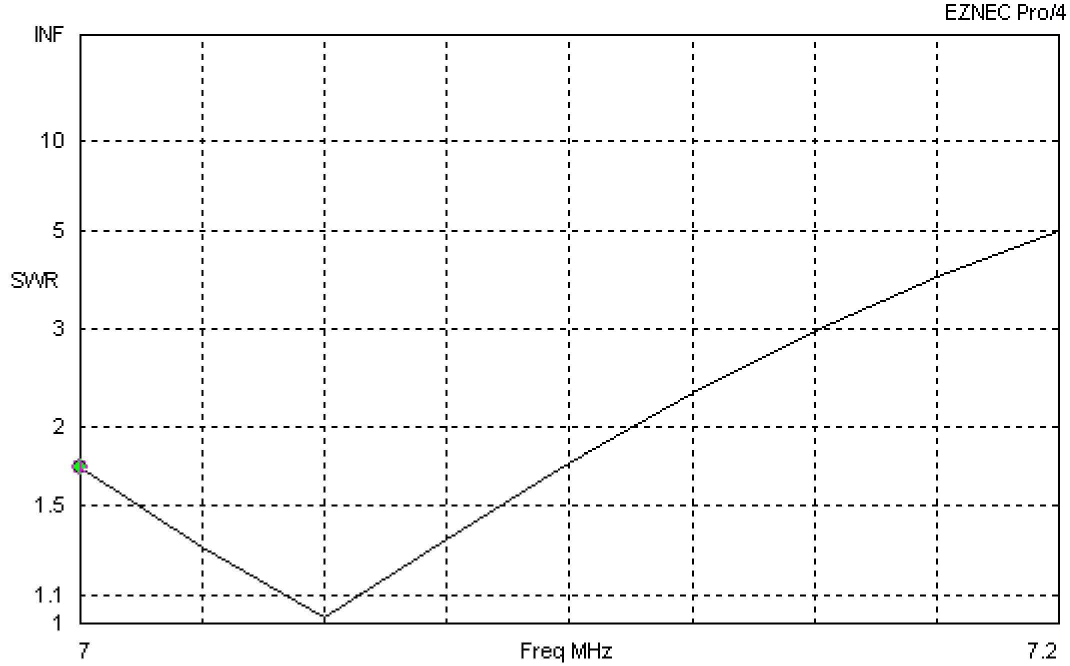


Azimuth Plot
Elevation Angle 15.0 deg.
Outer Ring 13.37 dBi

Cursor Az 0.0 deg.
Gain 13.37 dBi
0.0 dBmax

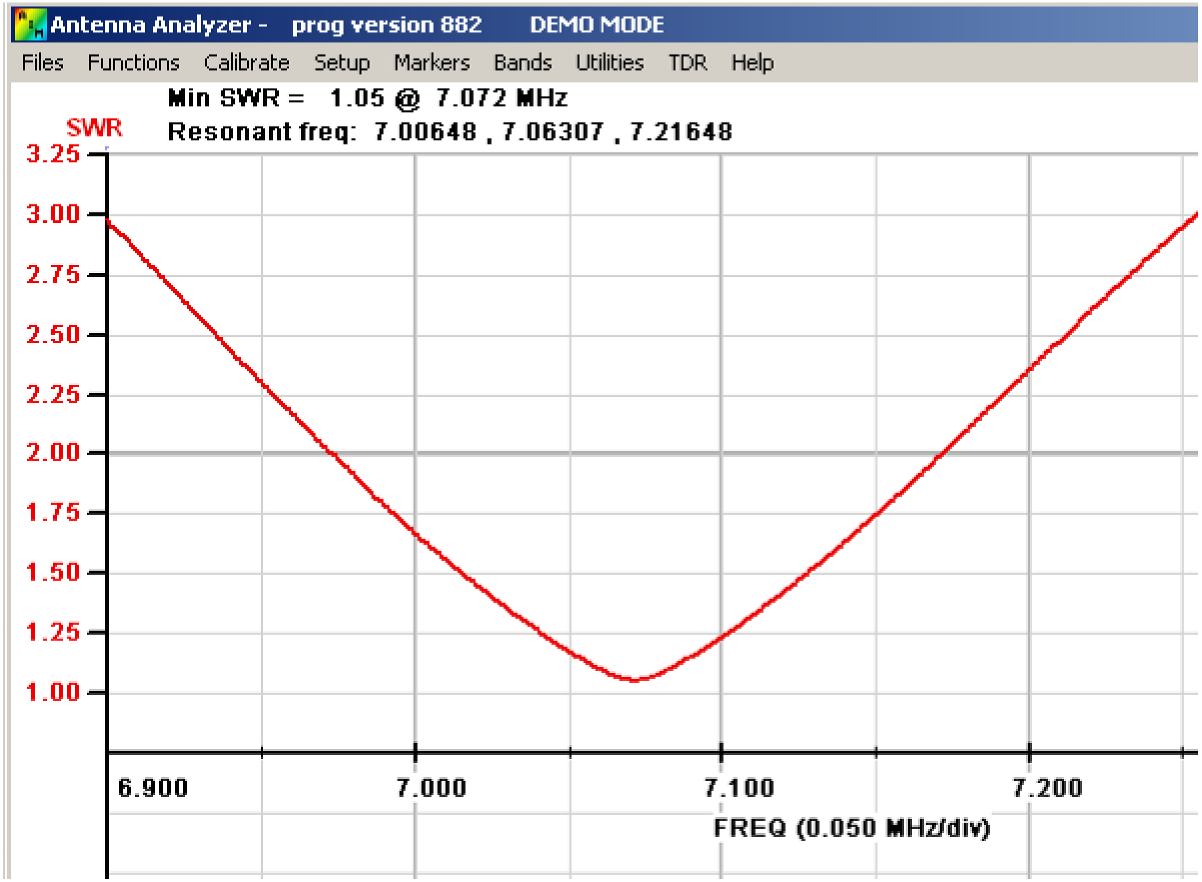
Slice Max Gain 13.37 dBi @ Az Angle = 0.0 deg.
Front/Back 18.59 dB
Beamwidth 73.0 deg.; -3dB @ 323.5, 36.5 deg.
Sidelobe Gain -5.22 dBi @ Az Angle = 180.0 deg.
Front/Sidelobe 18.59 dB

Modeled SWR, 7050kHz position, at the box input

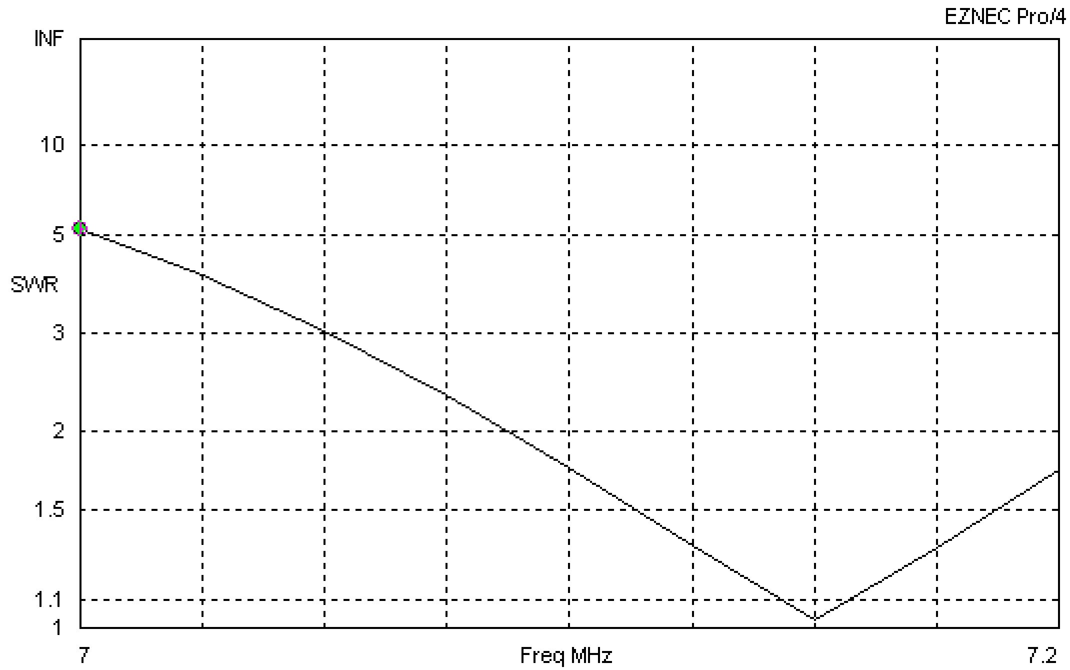


Freq	7 MHz	Source #	1
SWR	**1.73**	Z0	50 ohms
Z	34.23 at 21.45 deg.		
	= 31.86 + j 12.52 ohms		
Refl Coeff	0.2662 at 136.69 deg.		
	= -0.1937 + j 0.1826		
Ret Loss	11.5 dB		

Measured SWR in 7050kHz position, feed cable included



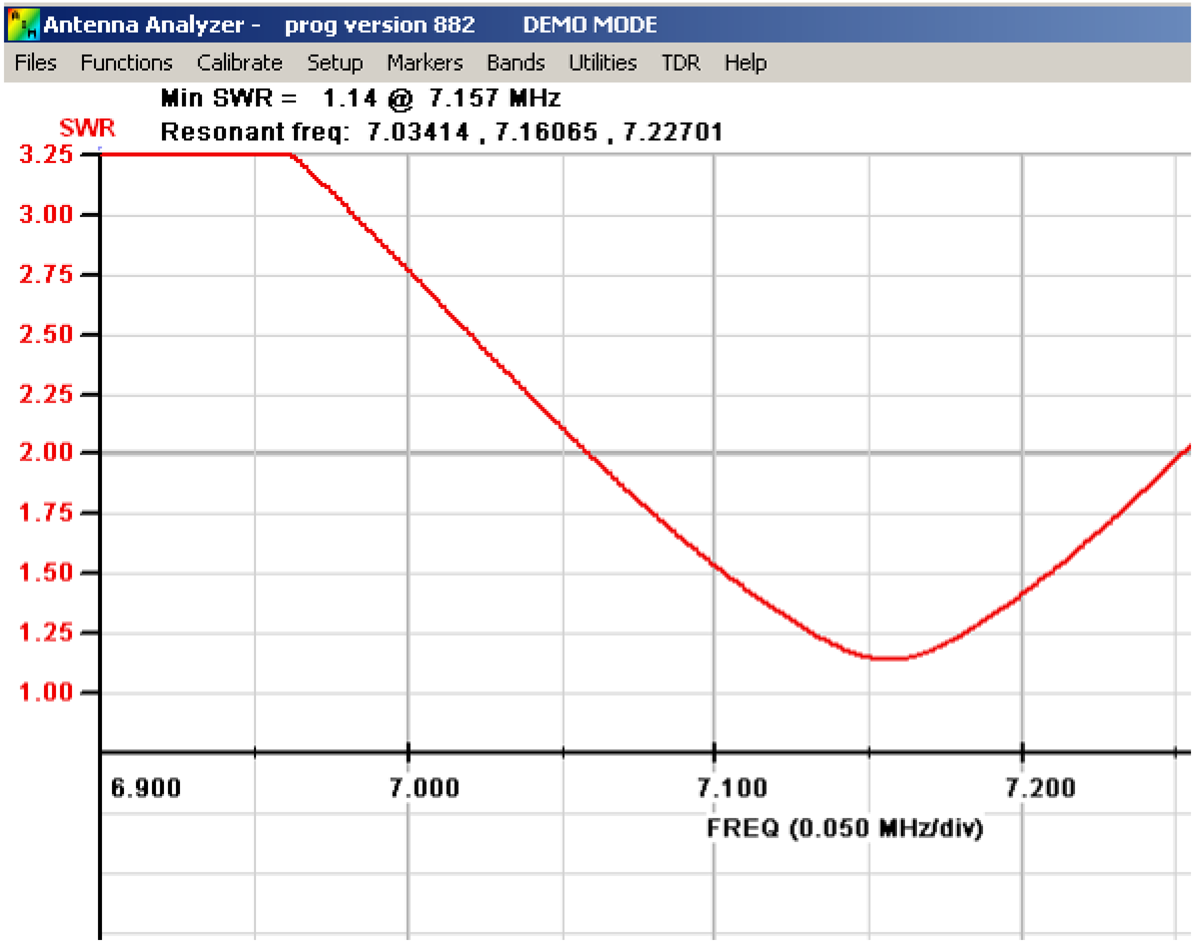
Modeled SWR in 7150kHz position, at the box input



Freq	7 MHz
SWR	**5.19**
Z	11.79 at 33.64 deg.
	= 9.813 + j 6.528 ohms
Refl Coeff	0.6767 at 164.54 deg.
	= -0.6522 + j 0.1803
Ret Loss	3.4 dB

Source #	1
Z0	50 ohms

Measured SWR in 7150kHz position, feed cable included



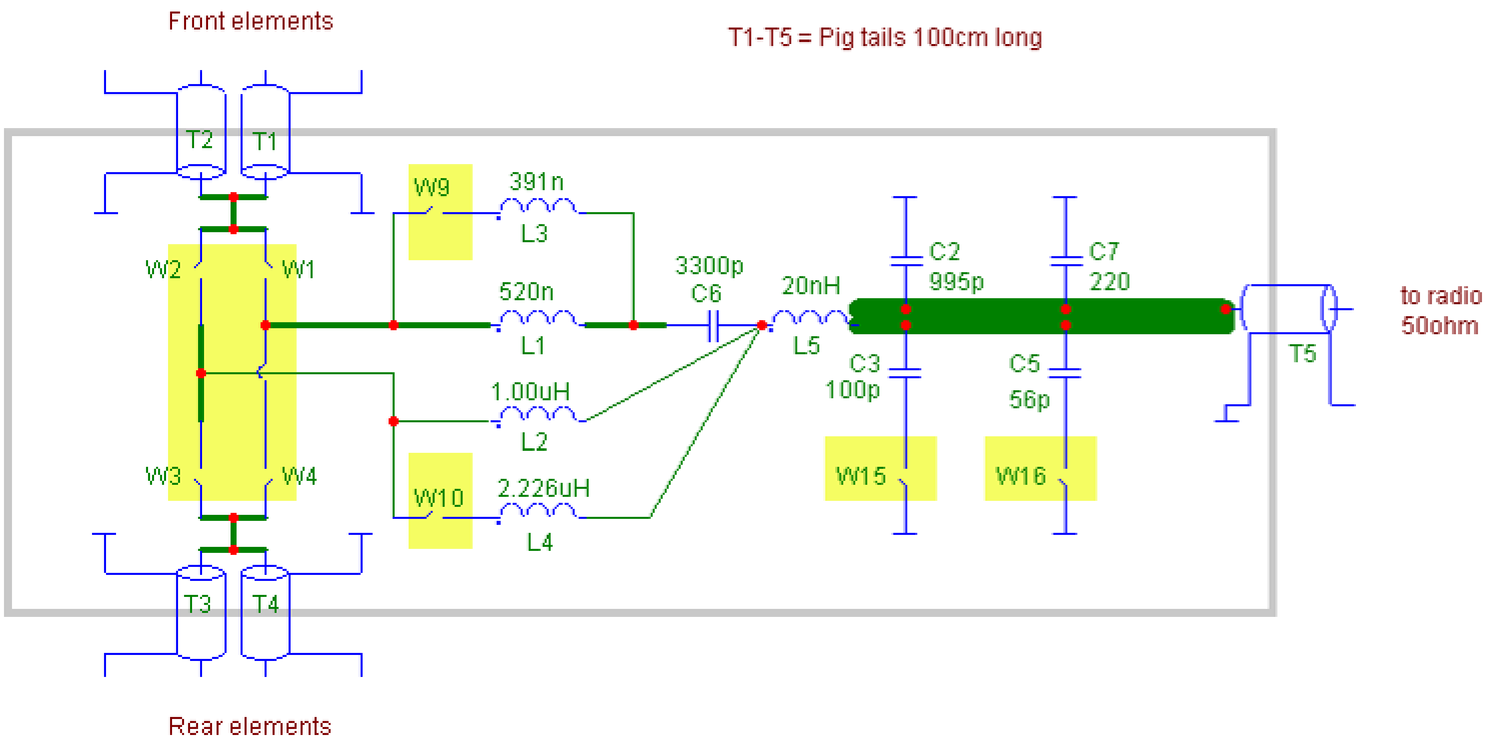
Structure

Elements and cabling

- Elements are about 15m long, coil loaded
    - Q of the coils is about 230
    - All four elements are similar and tuned to 7100kHz
    - Elements are made by Finnish Antenna Ltd and are similar to elements used in their popular JP7-2 Shorty – antenna
- ½ lamda long cables connect all four elements to the phasing box
    - Electrical lengths of those cables are 21.11m @7100kHz
    - Cable type is Ecoflex 15 Plus, v=0.86, dia 14.6mm
    - Physical lengths are 18.09m, including pig tails from the box
        - 1m long pig tails connect feeds to the phasing box
    - Opposite cable polarity in front and rear elements
- Current baluns are used at each feed point
    - 8 pcs Amidon FB-43-1030 beads on each cable
- Horizontal element spacing is 5.65m
- Vertical element spacing is 20.00m
    - Upper elements are up 46m, lower elements 26m AGL
    - Small compromise was made because of other antennas planned for the tower. 21m spacing would have been optimum for vertical side lobe attenuation

Element to boom

Phasing box for 2x2el 40m array at OH2BH



Forwards / Backwards switching

Forward: W1, W3 are on
Backwards : W2, W4 are on

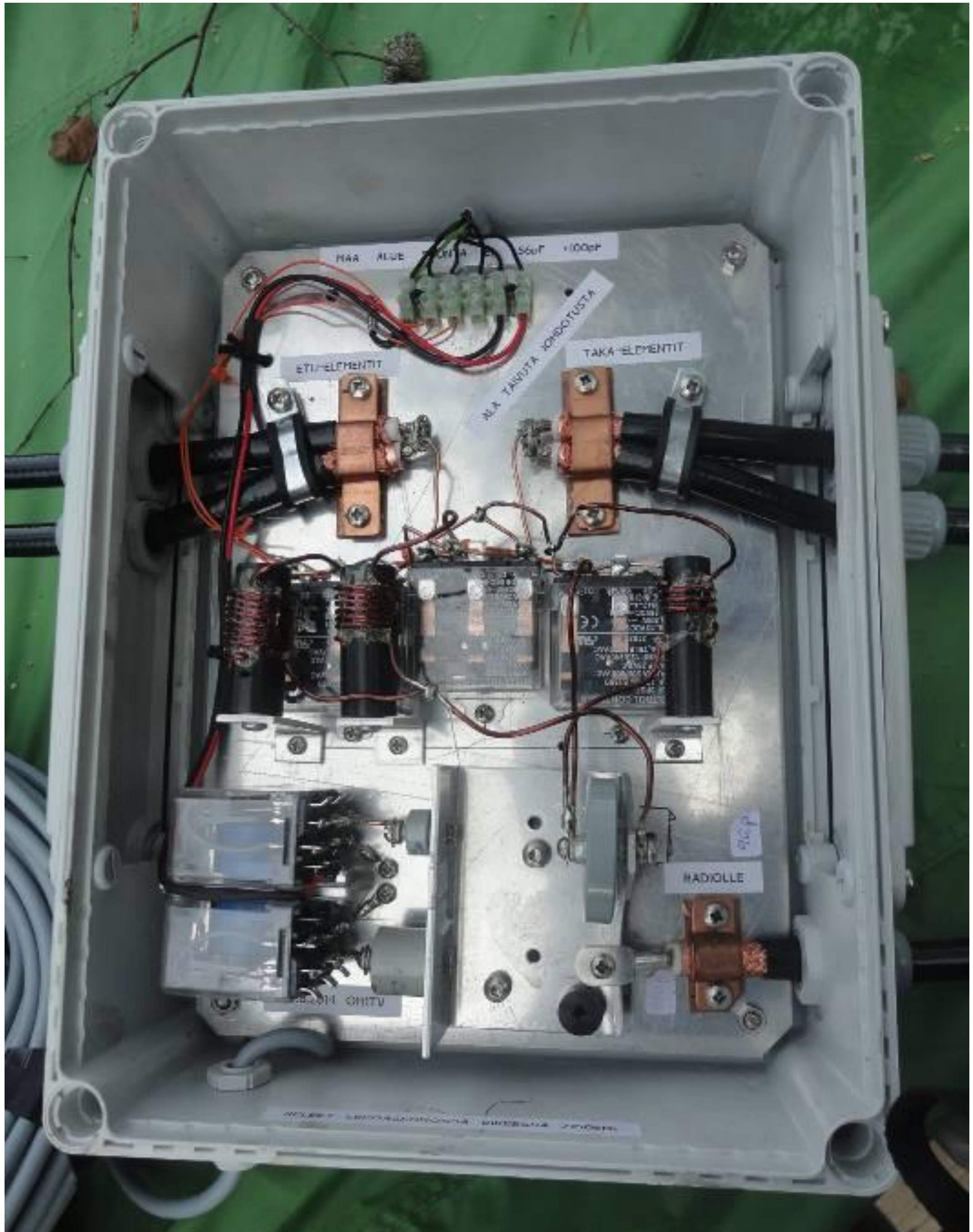
7050 / 7150kHz switching

7050kHz: releys W9,W10 are off
7150kHz: relays W9, W10 are on

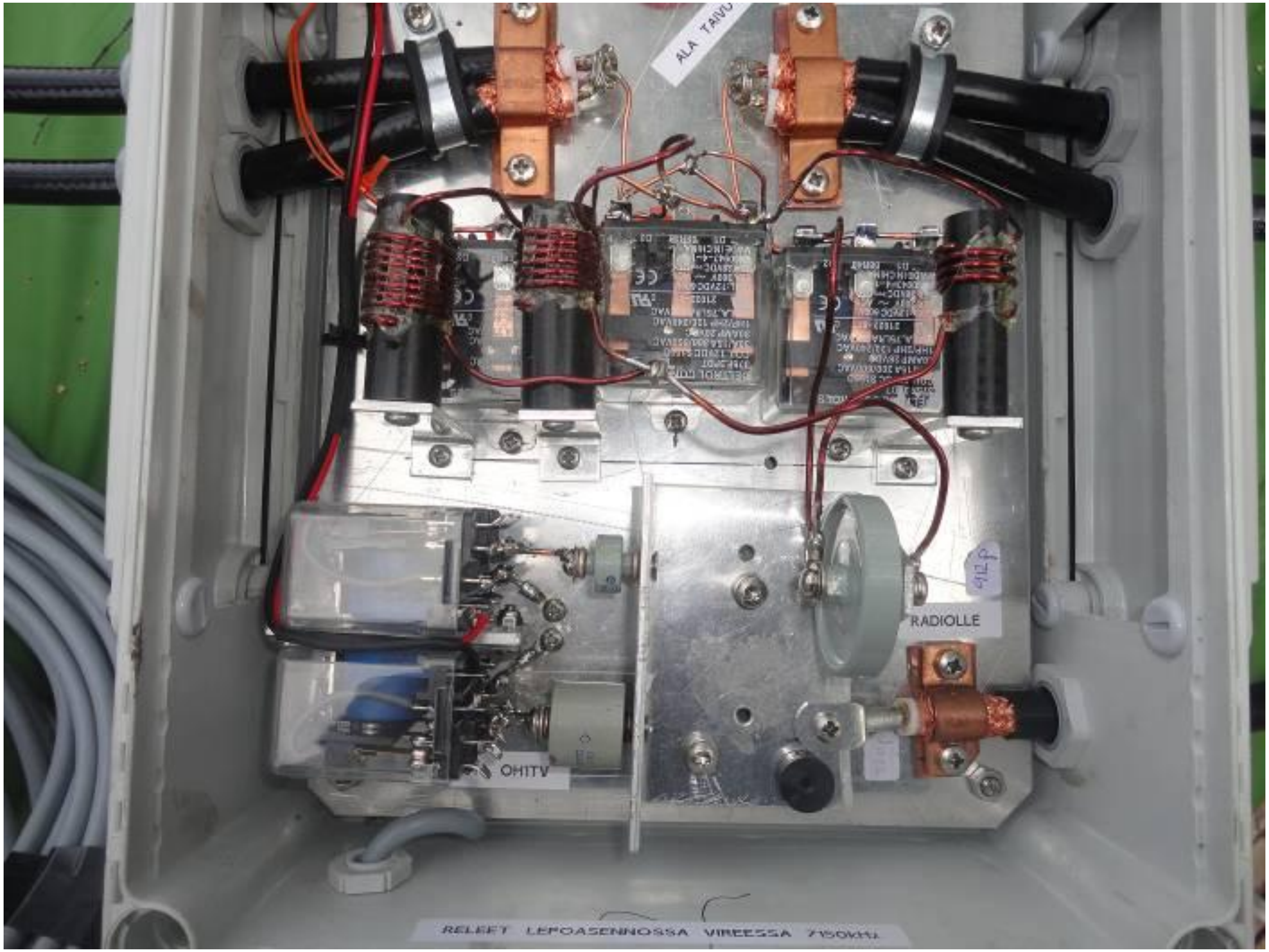
L-match, SWR tuning
7150kHz: W15 and W16 off
7050kHz: w16 on, w15 as a spare

8.8.2014
OH1TV

The Box


ETU-ELEMENTIT
TAKA-ELEMENTIT
ÄLÄ TARJOTA JOHDOTUSTA
RADIOLLE

The Box


ALA TAIVU
RADIOLLE
OH1TV
RELEET LEPOASENNOSSA VIREESSA 7150kHz

Tuning

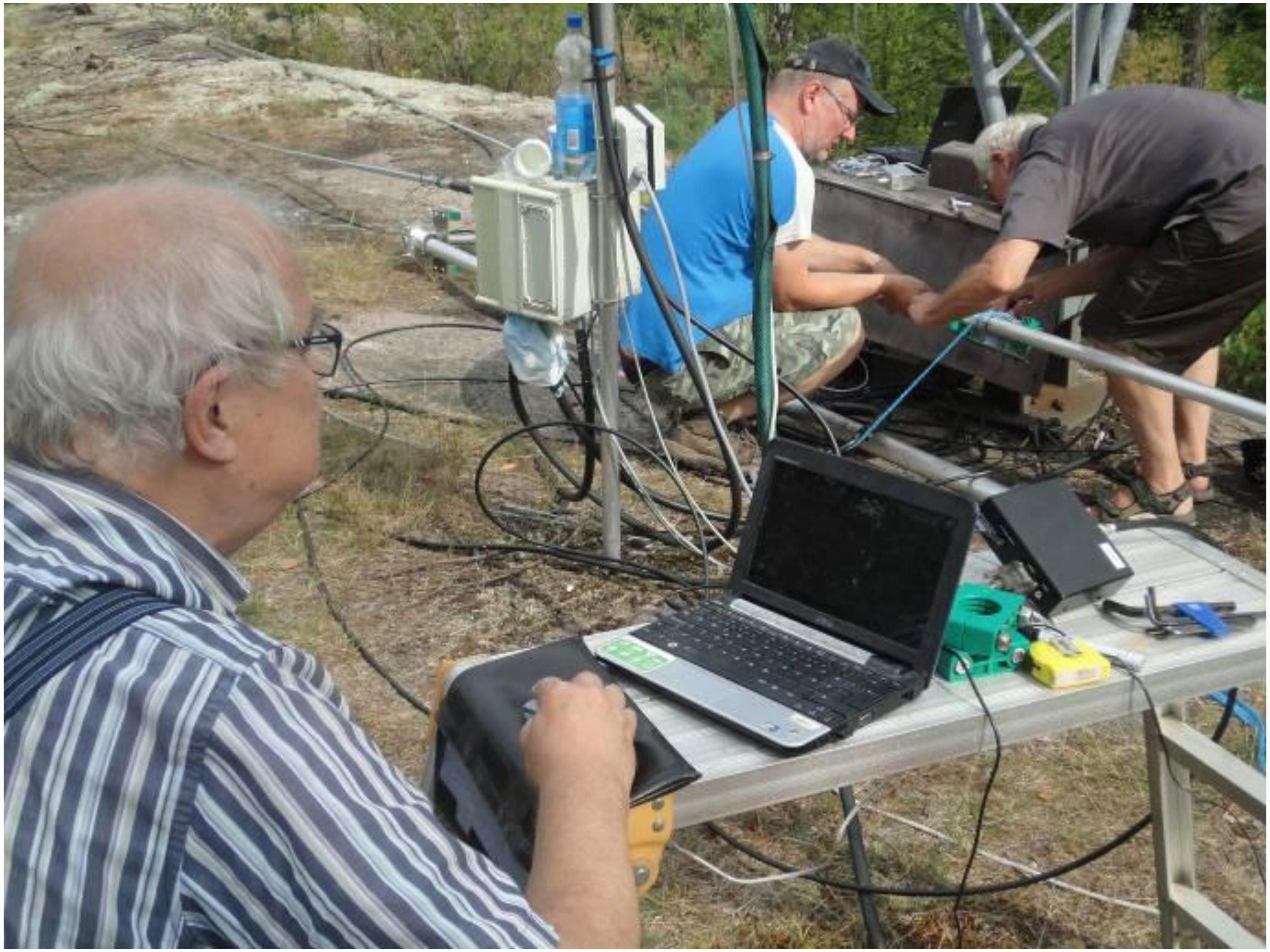
How it was aligned

- All four elements were tuned to 7100kHz +/- 5kHz
  - Measurements were made at 46m, which is the same as height of the upper elements
  - The instrument was antenna analyzer AIM4170 from Array Solutions
  - Abt 50m long measurement cable was eliminated with calibration
  - Impedance at element terminals was measured
- All components for the phasing box were measured before installation
  - AIM4170 was used, all capacitors and coils were selected based on measurements
  - Also inductance of relays and wiring were measured on 7.1MHz
- Lay-out of wiring is critical as we play with small inductances
  - All stray inductances from wiring were taken into account
- Final alignment was based on serial reactance in each leg when the summing point was grounded (left end of L5).
  - The target values were from Eznec model
- After this lab alignment no in-situ tuning was made. The box was just connected and the system was ready to go

Elements were tuned to 7100kHz

Measurements were made at 46m AGL level

OH1TV, OH1JT and OH3UU in action



Installation

Ready for take-off..

OH2PM and OH8SR fastening belts

Going up..

Work completed

Martti Laine, OH2BH wrote:

EXPECTATIONS & RESULTS OF OPPOSITE VOLTAGE 2-OVER-2 ARRAY FOR 40M

In my discussions about this unique antenna concept developed by Pekka, OH1TV, I was thrilled by a variety of clever practical features that seemed to address several specific needs at my contest station. Here were my main issues at the point when we decided to proceed.

1: How much can you scale down the size of a 40M beam and still be assured of reasonable performance in terms of forward gain with an acceptable front-to-back ratio while maintaining the advantage derived from antenna stacking? <u>I was specifically interested in the extraordinarily good F/B ratio of this design. Is it true?</u>

2: The benefits of a smaller size of the lower beam of the stack can be further increased, as the beam can rotate below the guy wire base <u>because of the reduced turning radius</u>. <u>The higher the lower antenna, the better the compensation from resulting coil losses.</u>

3: The option of <u>instant 180 degree direction switching</u> would dramatically enhance operating performance as with the click of a switch I could then quickly pick up stations calling off the back of the beam but at the same time, with <u>a good front-to-back ratio and eliminated unwanted side lobes, ensure clear receive from the desired main direction.</u>

4: While coil beams are known to be hampered by <u>narrow bandwidth</u>, it seemed possible to design this array <u>to cover both CW and SSB segments</u>. The feature of switching the take-off angle - DX and local - was not considered for my application and this helped to simplify the design and the job of tuning the matching unit.

ACTUAL RESULTS IN REAL LIFE

1: My reference is an M2 40M4FS 4-element beam up at 40 meters (130ft) while the 2-element stack is mounted on another tower at heights of 47 meters (150ft) and 27 meters (90ft). The coil beam, Finnish Antenna 40M 2-element Shorty, comes with an element length of 15.2 meters (51ft) with a turning radius of 8 meters (26ft) with a precise stacking distance of 20 meters or 0.5 wavelength. <u>This array has surprised me with its superior performance when compared to a larger 4-element beam.</u> Thanks to N7NG, W9KNI, K7ZV and N2AJ for extensive testing sessions. To my total surprise, it has an F/B ratio of 25dB while the 4-element M2 falls behind with around 20dB. The 25dB F/B ratio and the ability to eliminate unwanted side lobes ensure a remarkably clear receiving capability. I am quite amazed. This does not fall short of the overall performance of any larger array systems.

2: Previously I had two 2-element full-size M2 40M2L beams stacked at 48 meters (160ft) and 20 meters (67ft). My question was whether the higher placement of the lower beam would compensate for any coil losses. <u>It came as another total surprise that even in terms of front gain, the resulting difference was not noticeable in any situation.</u> Therefore I treasure the F/B. It seems that no major coil losses will result from a smaller physical package that may better handle ice loading during our severe winters. Can we say that in this case small is beautiful?

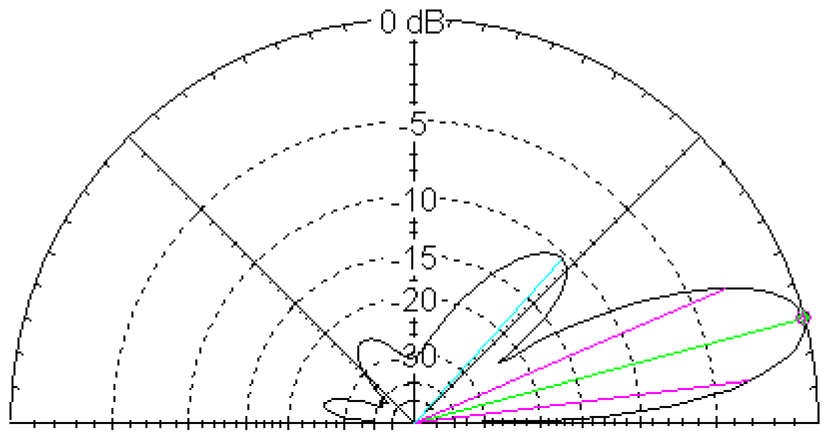
3: <u>Instant 180 degree switching is a truly amazing feature</u>. I can switch the antenna 180 degrees on a toggle switch or just check the rear on a push button. <u>I can immediately identify stations calling from unwanted directions and I do not need to search for those signals with a large rotating beam</u>. Just hit a push button to get them into the log with no delay. With a 25dB F/B I typically do not hear the stations calling off the back of the beam but with an occasional check I find an entirely different world out there. Perhaps "unwanted" is actually my new positive discovery resulting in increased scores. "Unwanted" becomes desperately wanted with a faster intake of stations with no need to turn the beam.

4: In Europe the 40M band extends from 7000 to 7200 kHz. <u>As the resulting bandwidth</u> could not be covered with coil beams, the band had to be divided into two segments. <u>A configuration of two 100 kHz segments was achieved easily</u> - the upper segment right on target (7160 kHz) and the CW segment centered a bit high (7075 kHz) with no tuning. So, 100 kHz bandwidth with a better than 1-to-1.5 SWR makes my amplifier happy, too.

Comparative analysis

How much the the coils reduce gain?

Total Field   EZNEC Pro/4



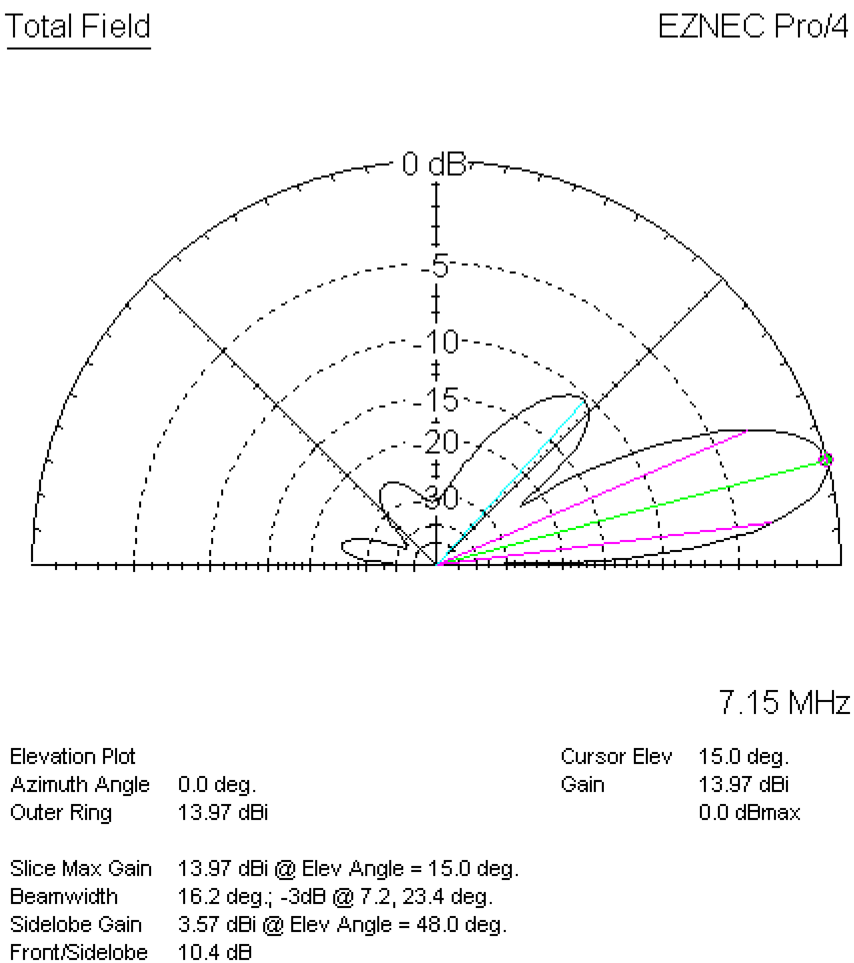
7.15 MHz

Elevation Plot		Cursor Elev	15.0 deg.
Azimuth Angle	0.0 deg.	Gain	13.79 dBi
Outer Ring	13.79 dBi		0.0 dBmax

Slice Max Gain	13.79 dBi @ Elev Angle = 15.0 deg.
Beamwidth	16.2 deg.; -3dB @ 7.2, 23.4 deg.
Sidelobe Gain	3.4 dBi @ Elev Angle = 48.0 deg.
Front/Sidelobe	10.39 dB

- Here we have similar antenna with lossless coils
  - main lobe gain is 13.79dBi.
- Main lobe gain with coils of Q=230 is 13.38dB, see earlier text
- >> Coil induced loss is 0.41dB

How much gain is lost by shortening elements?



- Here we have otherwise similar antenna but now with full size elements tuned to 7100kHz (20.3m dia 22mm) and phasing box adjusted accordingly. Main lobe gain is 13.97dBi.
- With the built antenna, 15m long elements and coils Q=230, gain is 13.38dBi, which is 0.59dB less than in full size antenna
- With 15m elements and lossless coils gain is 13.79dBi, which is 0.18dB less than in full size antenna, all spacing and heights being the same
- >> Influence of shortening alone to the main lobe gain is -0.18dB
- Shortening has no influence on vertical sidelobe attenuation on center frequency

Conclusion

Differences between shortened and full size arrays

- This simple analysis shows that our 2 over 2 stack with 15m long elements and coils with Q=230, has 0.59dB less main lobe gain than similar full size antenna, when differences in elements are taken into account.
- As impedance levels are lower in shortened antenna, losses in the phasing box may be a bit higher. This can be eliminated with conservative dimensioning however. This way total difference in gain is less than 1dB
- There is no difference in achievable F/B if the phasing concept is similar
- There is a difference in bandwidth in all respect: SWR, F/B, gain, but
  - This can be eliminated by using two 100kHz sub-bands
  - Those band tuning coils are easily integrated into the phasing components in the box