Rx antennas at IV3PRK: INTERACTIONS

A study on interactions between antennas on low bands.

by Pierluigi "Luis" Mansutti, IV3PRK

"DXing on the Edge", as the title of the book by Jeff, K1ZM, is the spirit of Topband. On 160 meters, rather than broadcasting, we must bother to pull out of the noise very weak signals, sometimes only a whisper, and a single dB of improvement in the S/N ratio makes the difference! An old rule says: "on low bands you never have enough antennas" and we have all experienced that on some occasions the desired signal is best copied on an unexpected antenna or a random wire. So, in the last 15 years I have been trying to fit every kind of receiving antenna on my one-acre lot, I have buried hundreds of meters of coax cables and also stretched, in the winter season, some Beverages outside my property, whatever possible. One acre is about 40 by 100 meters, quite a respectable lot if compared to a typical suburban one, but 40 meters is just a quarter wavelength on 160: how many interactions could happen among a mess of (resonant) wires within such a space?

With modelling programs, we learnt to deal with antennas, but we have been always accustomed to see them alone, depicted by a neat 2D or 3D pattern. Anyway, before going into the complex environment of all the antennas together, let us analyse the single subjects as stand alone.

The RDF concept

For every antenna or configuration, I generated the 3D Far Field Plots in order to get the average gain and calculate the "RDF – Receiving Directivity Factor" which is a very interesting and effective parameter introduced by Tom, W8JI, (www.w8ji.com/) to evaluate the receiving antennas. RDF is a very simple concept: it is defined to be the difference between the forward gain of an antenna (usually the maximum forward gain) and the average gain of the same antenna. The average gain is computed by adding the gain in all possible directions and dividing by the number of directions; so, if you put the 3D step size to 5, Eznec calculates 2.592 directions, and if you put it to 1, the computed directions are 64.800! And 1.500 segments mean 97 million computations for every run ...surely it slows even a Pentium4 800Mhz CPU (with no significative different results from lower step sizes).

Most of the receiving antennas have negative gain, but that's not a problem for the high sensitivity of modern receivers. If the signal is masked by noise, it does not matter how strong the signal is, but what is the S/N ratio. We need to have the desired signal rise enough above the noise so that we can separate it from the noise, which is usually coming from many random directions. RDF is the difference that the antenna itself provides between the favoured direction, and all other directions.

In the case of RDF, each dB improvement means that if you are trying to dig a signal out of the noise, all other signals and noise are reduced by 1 dB and, even if a decibel very small, at this level it seems much more meaningful. For the universe of receiving antennas practical RDF values varies by less than 10 dB.

Wide and very instructive pages on this matter with ranking of several receiving antennas can be found on the web pages of Greg Ordy, W8WWV (www.seed-solutions.com/gregordy).

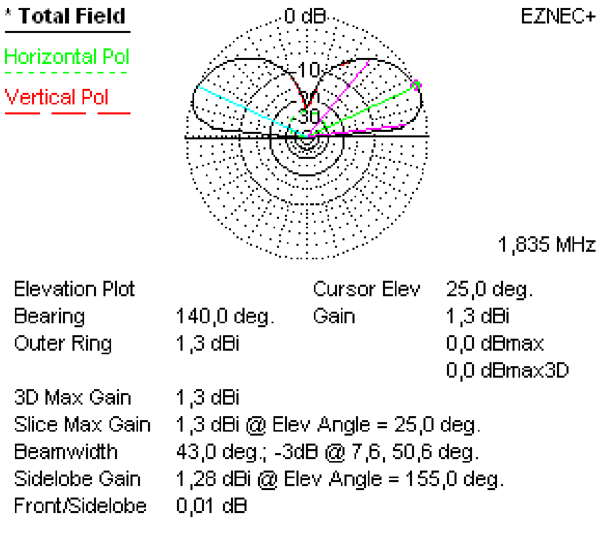
The basic EZNEC models

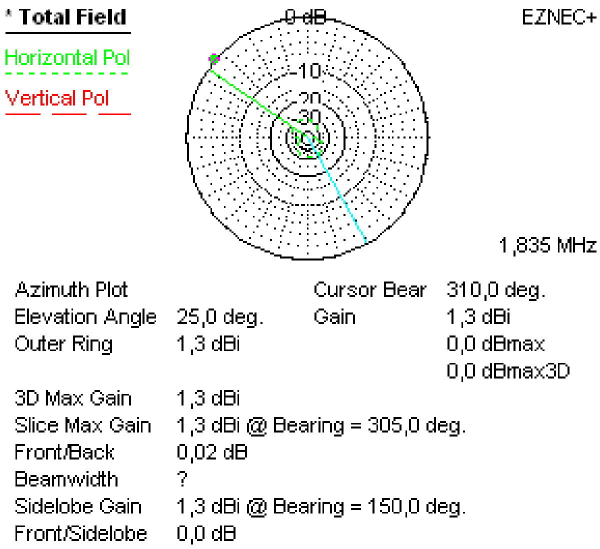
For every model, I indicated in a tabular form the name of the Eznec file with the number of wires and segments involved in the calculations, and the output source data for impedance matching, followed by the simplified elevation and azimuth plots.

The TX Vertical.

The plots of the vertical are classic, with a take-off angle of 25 degrees, good for DX, and a positive gain, that means antenna efficiency, needed for transmitting; the inductive source reactance is matched by the gamma capacitor. Note that the RDF is very low and does not change with the improved efficiency of the 32 radials model, confirming that the vertical is still receiving "equally poor" from all directions, independently from the radial system.

File	wires	segments	gain	TO angle	Avg.gain	**RDF**	Source Resistance	Source Reactance	
Tower-4	55	129	1,30	25	- 3,76	**5,06**	31,80	+34,84	4 ¼ wave elevated radials
Tower-32	162	376	1,73	25	- 3,34	**5,07**	34,95	+47,78	32 ¼ wave on ground radials

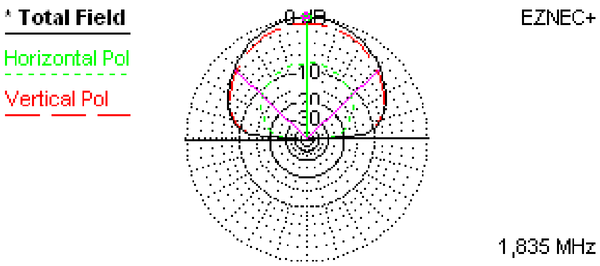




The Low Dipole.

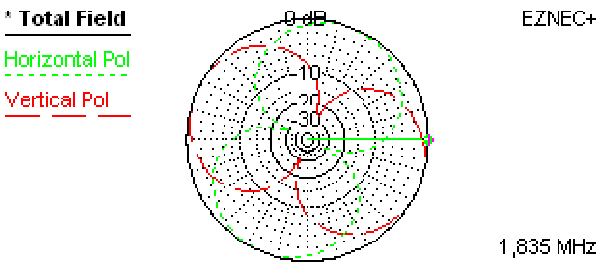
The low dipole is a classic case of poor efficiency; it resonates perfectly on 1.830 and if you run an SWR plot, you see an ideal sharp 50-ohm match, but the negative gain indicates a prohibitive transmitting loss. Anyway, it could be used as a receiving antenna. The RDF is better than that of the TX vertical because, rather than "equally poor" from all directions at wide low angles, the low dipole receives still "equally poor" but from fewer high angle directions, right down at 90 degrees. This high take-off angle is useful, besides for local work, also in some particular occasions, near sunrise, when a DX signal is coming "down" from an "E layer" hole at the end of ducting conditions. But, as we will see later, a low dipole must be kept far away from other antennas.

File	wires	segments	gain	TO angle	Avg.gain	**RDF**	Source Resistance	Source Reactance
Low dipole	2	30	- 2,70	90	- 10,00	**7,30**	50,42	1,12



Elevation Plot | Cursor Elev 90,0 deg.
Bearing 0,0 deg. | Gain -2,7 dBi
Outer Ring -2,7 dBi | 0,0 dBmax
0,0 dBmax3D

3D Max Gain -2,7 dBi
Slice Max Gain -2,7 dBi @ Elev Angle = 90,0 deg.
Beamwidth 92,3 deg.; -3dB @ 43,4, 135,7 deg.
Sidelobe Gain < -100 dBi
Front/Sidelobe > 100 dB



Azimuth Plot | Cursor Bear 90,0 deg.
Elevation Angle 90,0 deg. | Gain -2,7 dBi
Outer Ring -2,7 dBi | 0,0 dBmax
0,0 dBmax3D

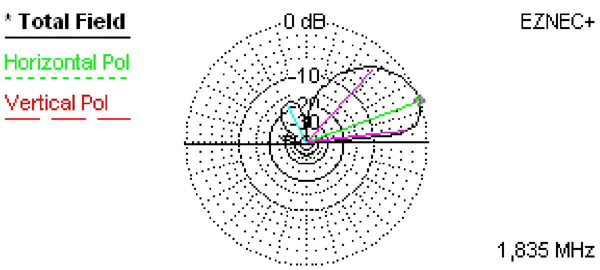
3D Max Gain -2,7 dBi
Slice Max Gain -2,7 dBi @ Bearing = 90,0 deg.
Front/Side 0,0 dB
Beamwidth ?
Sidelobe Gain < -100 dBi
Front/Sidelobe > 100 dB

The 4-Square Mini-Phased Array.

Built in 1994 with the help of the authors K9UWA and KD9DV, this has been for many years my best receiving antenna. It uses four vertical dipoles, expanded from the original design (ARRL Antenna Compendium Vol.3) to 10 meters, at 13 meters from each other and fed in a broadside, plus end-fire, configuration with a 155 degrees phasing. There is a wide use of ferrite stuff for loading, matching and decoupling the elements. The entire thing is quite critical, and, at this time, a revision work should be done for balancing and tuning again.

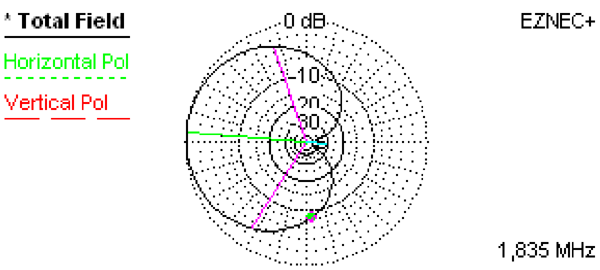
The pattern is very good at the desired low angles, with a sufficient signal level (i.e. a moderate negative gain) that does not require an outside preamplifier.

File	wires	segments	gain	TO angle	BW	FB	Avg.gain	**RDF**
4-square	4	60	- 5,86	20	127	30	- 15,23	**9,37**



Elevation Plot | Cursor Elev 20,0 deg.
Bearing 175,0 deg. | Gain -5,86 dBi
Outer Ring -5,86 dBi | 0,0 dBmax
0,0 dBmax3D

3D Max Gain -5,86 dBi
Slice Max Gain -5,86 dBi @ Elev Angle = 20,0 deg.
Beamwidth 40,4 deg.; -3dB @ 7,5, 47,9 deg.
Sidelobe Gain -23,02 dBi @ Elev Angle = 115,0 deg.
Front/Sidelobe 17,16 dB



Azimuth Plot | Cursor Bear 175,0 deg.
Elevation Angle 20,0 deg. | Gain -14,23 dBi
Outer Ring -5,86 dBi | -8,37 dBmax
-8,37 dBmax3D

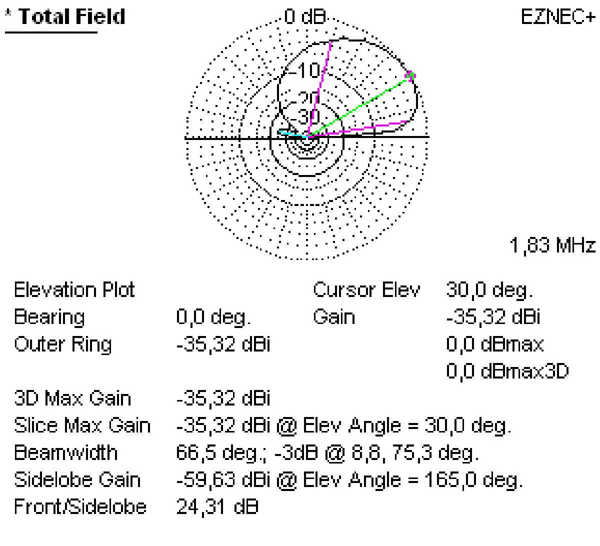
3D Max Gain -5,86 dBi
Slice Max Gain -5,86 dBi @ Bearing = 275,0 deg.
Front/Back 30,34 dB
Beamwidth 127,7 deg.; -3dB @ 213,0, 340,7 deg.
Sidelobe Gain -36,2 dBi @ Bearing = 95,0 deg.
Front/Sidelobe 30,34 dB

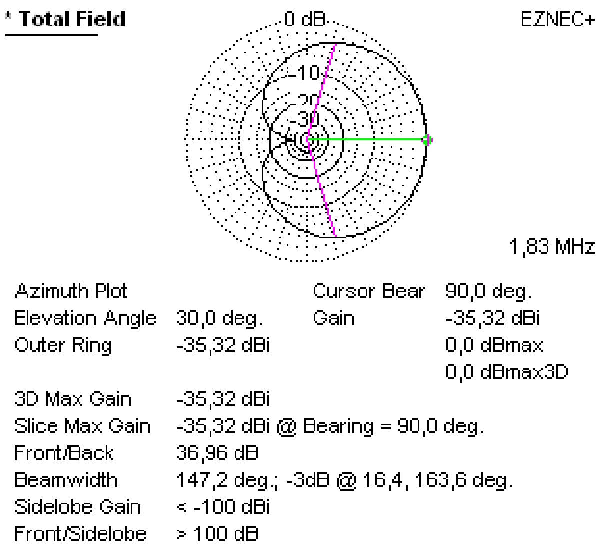
The Pennants.

Pennants and Flags have been introduced by Earl W. Cunningham, K6SE, with a July 2000 article on *QST Magazine*. One of the most attractive peculiarities of this family of receiving antennas, originated by an idea of Josè, EA3VY, is their independence from the ground characteristics beneath them.

The following is the output from the original EZNEC model by K6SE, just with segments number reduced to fit into the whole complex antenna environment.

File	wires	segments	gain	TO angle	BW	FB	Avg.gain	**RDF**
Pennant-1-standard	4	112	- 35,32	30	147	37	- 43,11	**7,79**

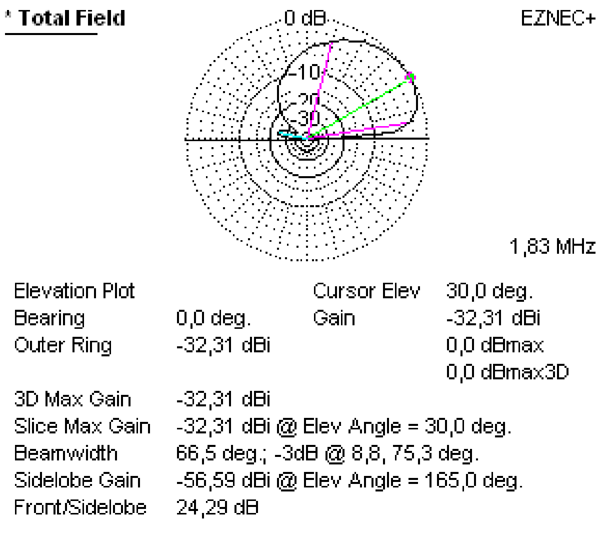


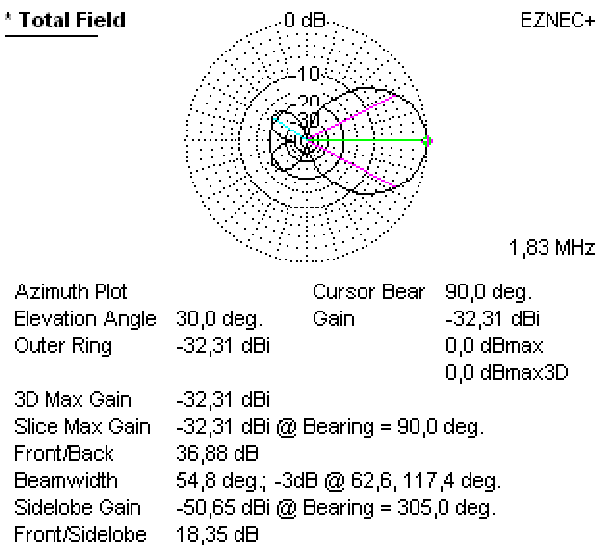


Bradside Pennants.

The following are the same Pennants, perfectly parallel to each other with 96 meters of separation, and fed in an ideal broadside configuration.

File	wires	segments	gain	TO angle	BW	FB	Avg.gain	**RDF**
Pennant-b-standard	8	224	- 32,31	30	55	37	- 43,32	**11,01**



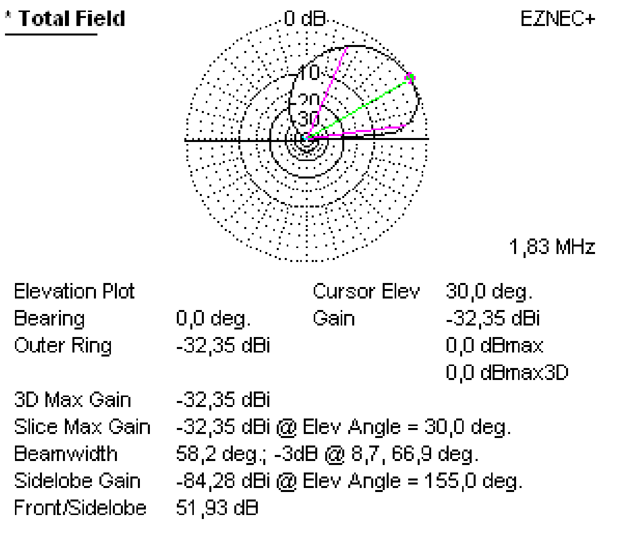


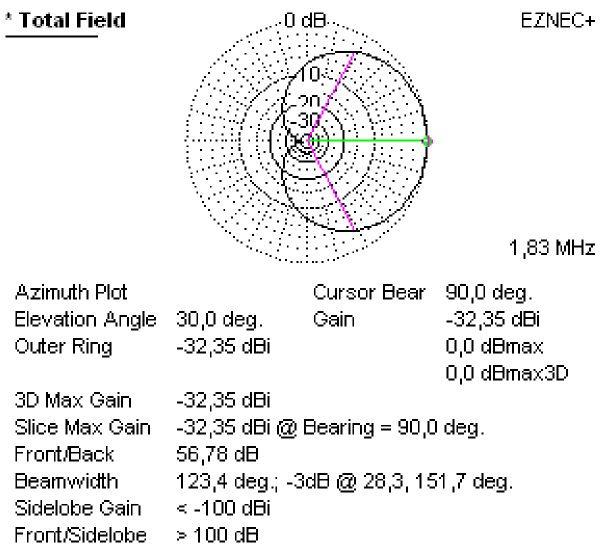
With broadside, the RDF jumps to 11 dB, more than 3 dB of improvement over a single Pennant, much better than in the following end-fire configuration.

End-fire Pennants.

Still from K6SE model, two Pennants, perfectly in line to each other with 41 meters of separation, and phased with 90 degrees difference in an ideal end-fed configuration.

File	wires	segments	gain	TO angle	BW	FB	Avg.gain	**RDF**
Pennant-e-standard	8	232	- 32,35	30	123	56	- 41,22	**8,87**





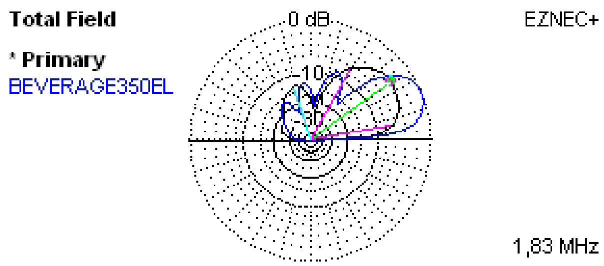
The reference Beverage.

As outlined in Fig.2, there are also two winter Beverages (outside my property) which cannot be added in the complex environment for their particular modelling technique. It appears to have two ¼ wavelength radials at each termination at right angles, which cancel each other, since that' s the correct way of modelling a real ground connection with Eznec.

Anyway, the Beverage is for sure the best receiving antenna if you have enough space and ...several long ones will be better. Here is the Eznec file for a stand-alone, 1 wave-long one, as a reference, followed by a 2-waves long one (preferred cone-of-silence ranges: see "The Beverage Antenna Handbook" by Victor Misek W1WCR and "Low-Band DXing" by John ON4UN).

It is clear the outstanding performance we can get with a serious set-up of Beverages, certainly unrivalled.

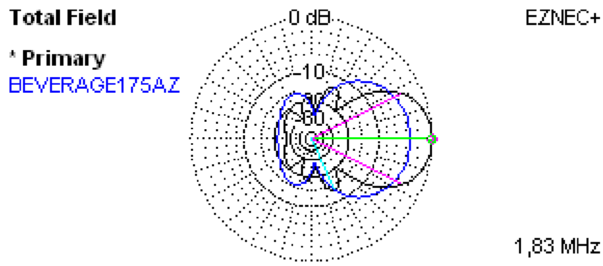
File	wires	segments	gain	TO angle	BW	FB	Avg.gain	**RDF**
Ref.Beverage 175 m.	5	48	- 9,82	36	84	18	- 20,63	**10,81**
Ref.Beverage 350 m	5	72	- 6,43	24	53	27	- 20,09	**13,66**



Elevation Plot | Cursor Elev 36,0 deg.
Bearing 0,0 deg. | Gain -9,82 dBi
Outer Ring -6,43 dBi | 0,0 dBmax
0,0 dBmax3D

3D Max Gain -9,82 dBi
Slice Max Gain -9,82 dBi @ Elev Angle = 36,0 deg.
Beamwidth 49,8 deg.; -3dB @ 10,3, 60,1 deg.
Sidelobe Gain -19,55 dBi @ Elev Angle = 108,0 deg.
Front/Sidelobe 9,72 dB

Primary trace and data : Beverage 175 meters long



Azimuth Plot | Cursor Bear 90,0 deg.
Elevation Angle 24,0 deg. | Gain -6,43 dBi
Outer Ring -6,43 dBi | 0,0 dBmax
0,0 dBmax3D

3D Max Gain -6,43 dBi
Slice Max Gain -6,43 dBi @ Bearing = 90,0 deg.
Front/Back 26,73 dB
Beamwidth 53,0 deg.; -3dB @ 63,5, 116,5 deg.
Sidelobe Gain -19,42 dBi @ Bearing = 156,0 deg.
Front/Sidelobe 12,99 dB

Primary trace and data: Beverage 350 meters long

Now, what happens when the examined antenna is getting currents induced from coupling with a nearby vertical, horizontal or sloping wire? Is a minimum separation rule required?

The answers can be found with the new product lately introduced by Roy Lewallen, W7EL: the "EZNEC+". It is "dedicated to the advanced experimenter..." with a 1500 segment capability aimed at the modeling of very complex antennas, especially for VHF and UHF use.

This is a very important feature, that upstages the standard 500 segment limits of all the other NEC2-based modeling programs, and I have been able to take full use of all that capability by putting together the transmitting and all the receiving antennas on my lot and managing an analysis of the stuff as a "whole antenna" by just switching the feeding points.

After reading this long report maybe we should amend that old rule, stated above, as follows: "on low bands you never have enough antennas, if you have enough space …otherwise they could be too many!"

The "antenna's scene environment"

As a first step, I took metric measurements on the field of all the antennas positions and put them down on a paper with the coordinates +/-X and +/-Y referenced to the "zero" origin point at the centre of the ground system.

I started modeling, from the original K6SE design, my actual two groups of point-fed Pennants and three further ones for future end-fire configurations. Good news at glance, I noted no interaction between any of the Pennants: actually, the point fed system let them work as absolutely isolated from each other.

Next, as detailed in the following spreadsheets, I began adding - it's a nice Eznec feature - the description of all the other antennas, one by one, in order to see what was going to happen, and than changing the source wires (feeding points) for every single run.

Fig.1 is a snapshot from Eznec "View Antenna" and represents the initial antennas scene with:

- the simplified top-loaded vertical with the real four ¼ wave elevated radials in use for 10 years; in realty it's a triangular shunt-fed, self-supporting tower (12 cm. diameter tubes) on a 140 cm. wide base tapering up slowly, with a 4 el. 15 m. Yagi as a top-hat for a total height of 27 meters. I adapted the Eznec model diameter to match the real R +jX measurements taken with the AEA –CIA analyser;
- all the 10 Pennants, from the K6SE model;

- the 4-square mini-phased vertical array by W7EL-KD9SV-K9UWA design, (ARRL Antenna Compendium, Vol.3) with the elements expanded to 10 meters high and sited about 60 meters from the TX antenna;
- an old low receiving dipole from a 6-meter tree sloping to 2 meters on a Pennant pole.

This corresponds to the worst situation, identified by the FPenn10-row in the spreadsheet tables and by the last added trace (in red colour) on the left-hand azimuthally plots.

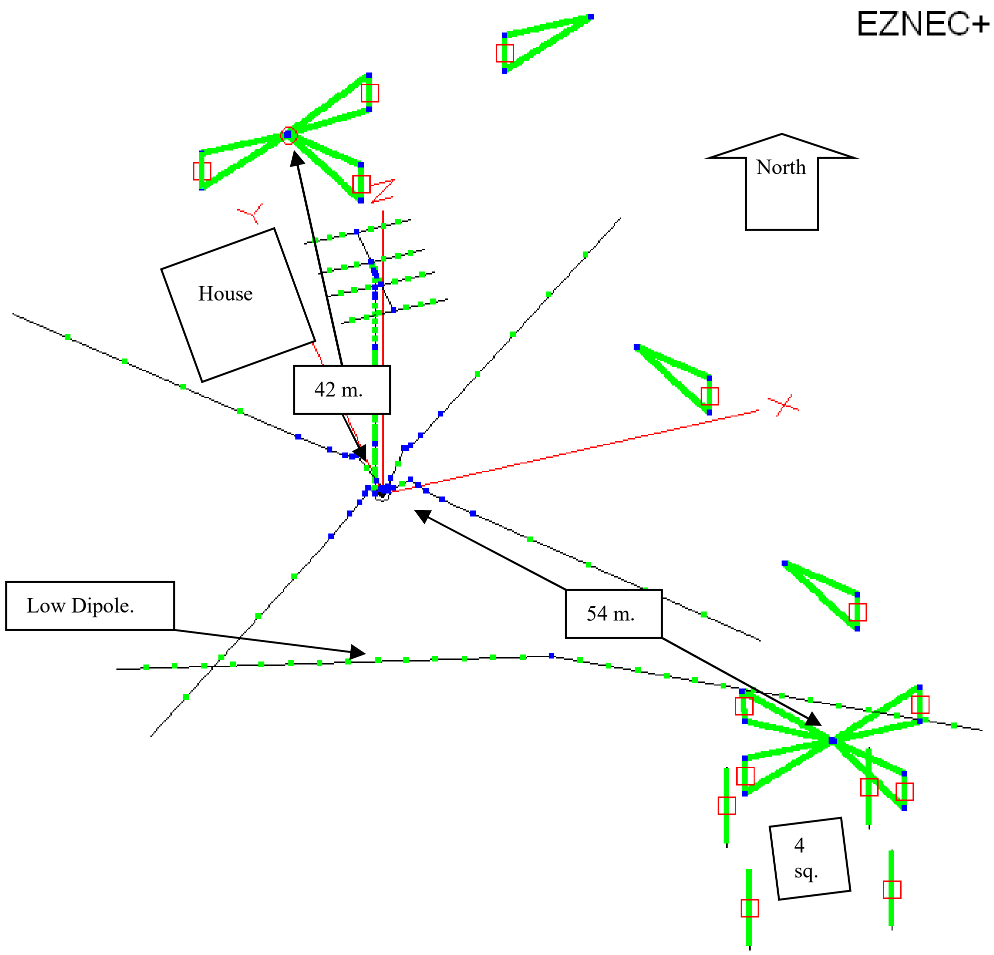


Fig.1

From that situation, I removed everything but the 10 Pennants (first row in the tables and primary trace on both plots), then I added new 32 ¼ wave on ground radials (row BPenn10-) and then I added again also the 4-square (row GPenn10-). In five cases I simulated also a detuned tower situation and thus there is a double row and double trace.

Finally, I took the resolution, after throwing away that harmful low dipole, to remove also the useless Pennant in the southern group. After checking and adjusting the on-ground radials and the number of segments, I made a last run at the highest precision step size – 1 degree – which is really time consuming (HPenn9-), identified by the last row in the spreadsheet tables and the last added trace on the right-hand azimuthally plots.

Noteworthy has been detuning the transmitting antenna: in almost all cases it is very pronounced with the 32 on ground radials, while it has no effect on the 4 elevated radials cases. That explains why I have been always unable to get any receiving improvement by trying to detune my tower and push me to change urgently the radial system!

Fig.2 is a snapshot of the “View Antenna” last row file “HPenn9” and represents the antenna scene with the best set-up after the analysis has been completed with:

- the same simplified top-loaded vertical with the 4 elevated radials substituted by a new “on ground” ¼ wave radial system. Actually, the radials are modelled 20 cm. high in order to satisfy one of the limitations of the NEC-2 engine which requires for any wire a minimum separation of 0,001 wavelengths from ground;
- the pennants reduced to 9 after removing the “NW-1s” which was too closed to the 4-square and could not add anything in the desired direction either in the broadside or end fire configuration;
- the same 4-square mini-phased vertical array, and
- the low receiving dipole has been definitely taken away!

On the same drawing, I outlined also the feed points of the two winter Beverages, but I could not model them due to the NEC-2 constraints. A Beverage is an antenna that needs the ground connection which is not allowed by the NEC-2 high accuracy/real ground type, common to my entire antenna scene. With Eznec the correct way of modeling a real short to ground is to connect two 0, 25 wave radials at right angles to each termination of the Beverage (see ON4UN Low-Band Dxing – chapter 7.3.2), but such technique should have presented false interactions in my environment. That is, even not actually present, there should have been computed further elevated resonant radials!

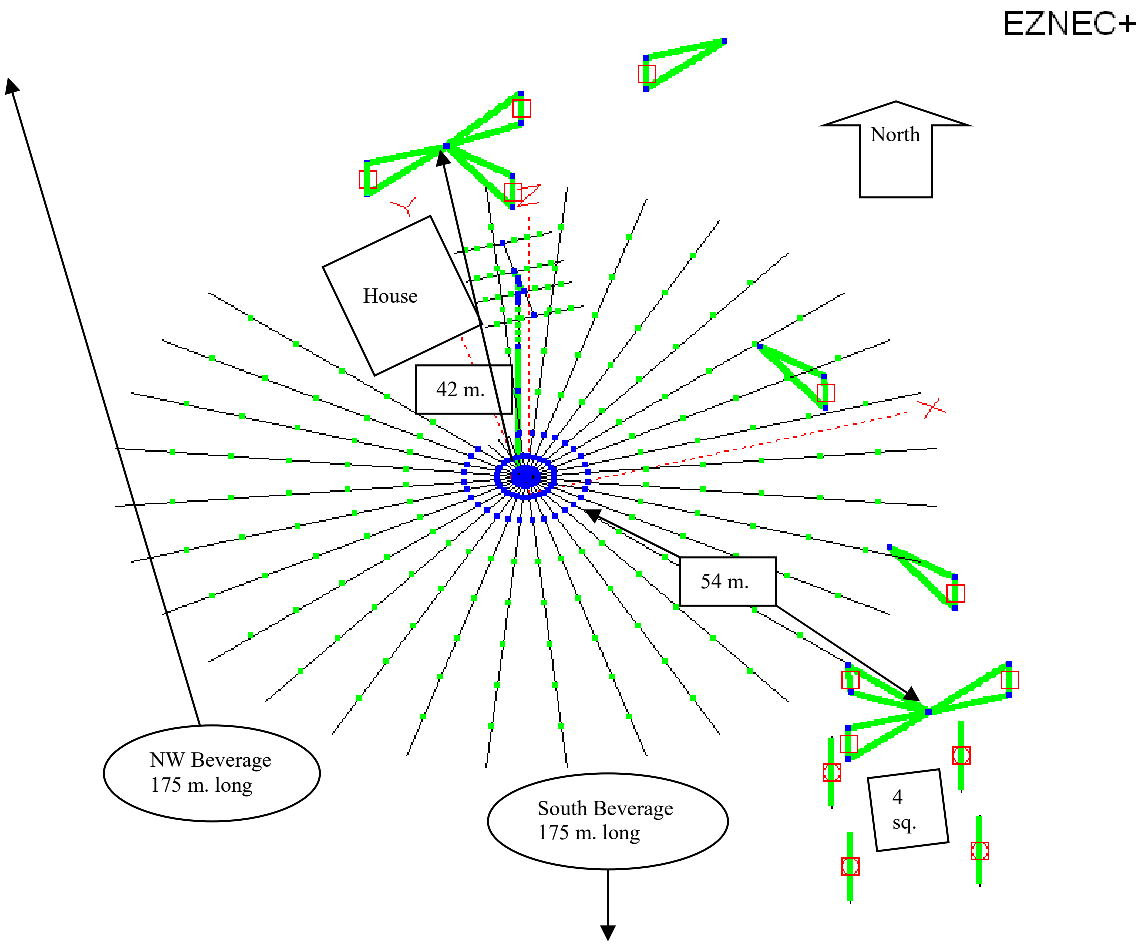


Fig.2

Running through the models

Sorry, I know it's very complicated… you can skip to the summary in the last page!

I built 8 different wires environments, and for each of them I ran all the possible source combinations for every single antenna or configuration, and each with a tower detuned variation. In order to proceed with so many files and runs, I was keeping trace of Eznec wires and outputs data on spreadsheets, which are partially copied down here for every target.

Each table reports:

-the antenna description with the main wires +/-X and +/-Y coordinates in meters (from the common origin at the TX antenna) and the source wire activated;

-the Eznec file / trace plot file name;

-the number of wires and segments involved;

-maximum gain in dB (negative) at the TO (take-off angle) and azimuth bearing;

-BW (-3dB beam-width);

-FB (Front to back ratio in dB) and RDF (Receiving Directivity Factor) as explained before.

In all tables, representing all the Pennants – as named, one by one - the first row with "APenn…" represents the Pennant alone, with no interactions with the others or from other kind of antennas and corresponds to the primary trace in both azimuth plots. In fact, the values in this row match exactly with those (and the plot) of the standard Pennant by K6SE.

- The row with "FPenn…" -double underlined- represents the worst case and corresponds to the last red trace in the left plot (added all the interactions) and represents the complex "Antenna View" of Fig.1.
- The last row with "HPenn…" -double underlined- represents the best case (hopefully) and corresponds to the last red trace in the right plot (after detuning and taking away the offenders) and represents the complex "Antenna View" of Fig. 2.

In most of the scenes I ran also a detuning tower option, at first by putting a reactive load on the TX antenna feeding point and than, after learning further EZNEC facilities, by defining a 90 degrees short stub through the transmission lines window (…the results are almost the same). These are the common EZNEC settings kept always fixed for all the models:

-Frequency: 1.835 MHz

-Ground type: Real/High Accuracy

-Ground description: Good/Average – Conductivity 0,005 S/m – Dielectric constant 13

-Wire loss: copper (it is not possible to use more than one material type on the same model)

-Step size: 5 degrees, except the last series (HPenn…-row) where 1 degree has been used.

The loads on the Pennants and on the 4-Square are those calculated by K6SE and W7EL, respectively, and never changed. The source is defined for every run and specified in the title row of each table.

All the runs and results are organized in the following order:

A) Single Pennants fired up in the designed direction as indicated in the table title and in every trace name (i.e.: NE-1n identifies the North-East Pennant in the northern group).

In realty these Pennants are split up in two groups and are point fed in two separate relay box where the secondary of an FT140-43 transformer is switched on both terminals of each Pennant. This is the source point, applied on a very short (3 cm.), one segment wire, which causes a "segmentation check warning" by Eznec program; but that doesn't hurt the results.

B) Pennants fired in broadside and endfire configurations (i.e.: NE-2br or NE-2ef).

In realty the broadside feeding is already in use, through a UNUN matching device, while the end-fire arrangements are on the paper and will make use of three new Pennants to be placed within my physical constraints only for this purpose.

C) The old 4-Square mini-phased array fired in its four directions, to see that the interactions are not reciprocal and it is not influenced by the Pennants.

NW-1n

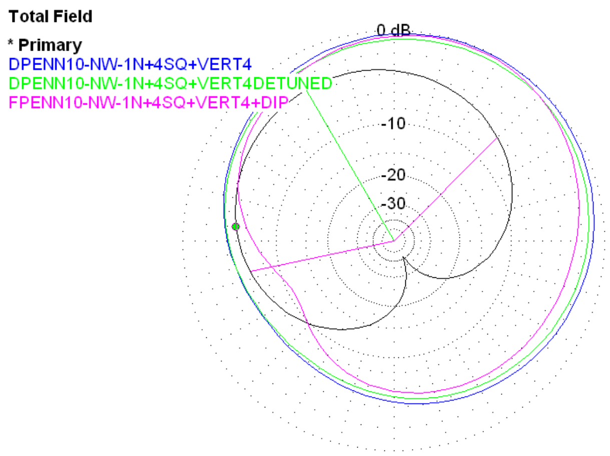
Single PENNANT bearing North West from wire 9 (X +9; Y+34,1) to > source wire 11 (X +4,8; Y +41,9)

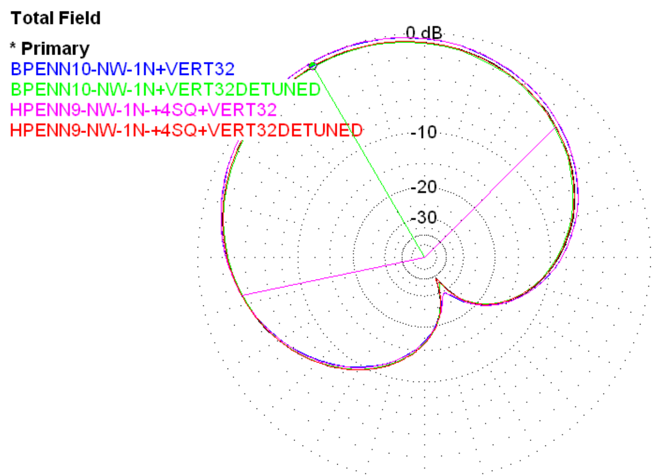
File	wires	segm.	gain	TO	Bearing	BW	FB	**RDF**	Description notes
Primary trace APenn10-NW-1n	40	1120	- 35,29	30	330	147	38	**7,80**	Only the 10 Pennants - 112 segments each
EPenn10-NW-1n	44	1180	- 35,29	30	330	147	38	**7,79**	Added the 4 square mini-phased array (wires 41-44)
CPenn10-NW-1n	95	1249	- 32,45	55	30	194	7	**7,26**	Added top loaded tower with 4 elev.radials (in use)
tower detuned			- 32,79	55	30	197	8	**7,24**	added a load of X -999 on wire 41
DPenn10-NW-1n	99	1309	- 32,08	60	35	216	6	**7,25**	Added again the 4 square array (wires 96-99)
tower detuned			- 32,53	60	35	220	6	**7,22**	added a load of X -999 on wire 41
FPenn10-NW-1n	101	1339	- 32,24	45	25	165	7	**7,31**	Added tower/4 elev.radials + 4 sq. + LOW DIPOLE
BPenn10-NW-1n	202	1496	- 34,99	30	330	144	29	**7,92**	Add.only the tower with NEW 32 radials on ground
tower detuned			- 35,35	30	330	146	34	**7,83**	added a load of X -999 on wire 41
GPenn10-NW-1n	206	1436	- 34,95	30	330	144	29	**7,93**	Added again the 4 square and reduced segments
tower detuned			- 35,24	30	330	146	33	**7,82**	added a TL 90 degrees short stub on wire 45
HPenn9-NW-1n	199	1426	- 34,98	31	333	144	29	**7,94**	Reduced to 9 pennants (deleted wires 25-28) and
tower detuned			- 35,30	31	332	146	37	**7,84**	increased segm. again to 112 each/ TL 90° short stub

This is the North-West Pennant in the northern group, located 36 meters from the TX tower and 65 meters from the low dipole, but 20 meters from an elevated radial, getting a disruptive action, even if at right angle with it.

The pattern looses completely its cardioid's shape going into a high-angle lobe without any directive characteristics; trying to detune the tower does not have any effect as the distortion comes from that radial first.

But after substituting the four elevated radials with on-ground radial system and detuning the tower with a quarter wave short stub, the performance of this single Pennant is the same as a standard stand-alone!





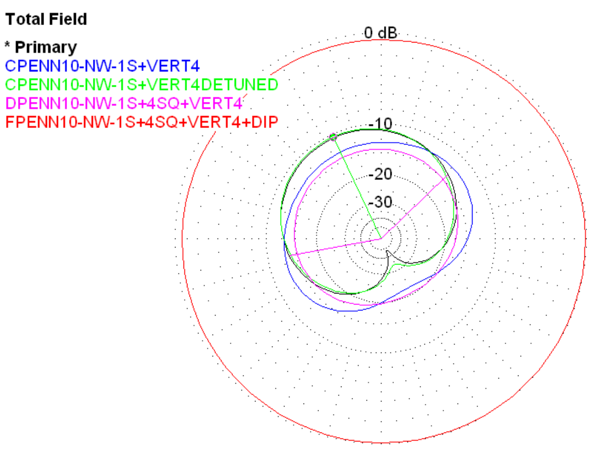
Azimuth Plot: worst case | Pennant NW-1n | Azimuth Plot: best case

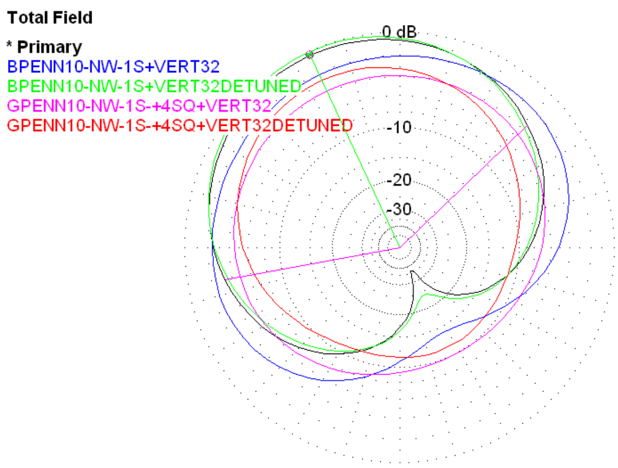
NW-1s **Single PENNANT bearing North West from wire 25 (X +31; Y -53,8) to > source wire 27 (X +27; Y -45,9)**									
File	wires	Segm.	gain	TO	Bearing	BW	FB	**RDF**	Description notes
Primary trace APenn10-NW-1s	40	1120	- 35,29	30	335	147	36	**7,80**	Only the 10 Pennants - 112 segments each
EPenn10-NW-1s	44	1180	- 37,93	35	335	137	8	**7,36**	Added the 4 square mini-phased array (wires 41-44)
CPenn10-NW-1s	95	1249	- 36,88	35	45	241	2	**6,15**	Added top loaded tower with 4 elev.radials (in use)
tower detuned			- 35,08	30	330	136	23	**7,96**	added a load of X -999 on wire 41
DPenn10-NW-1s	99	1309	- 39,00	65	345	235	6	**6,83**	Added again the 4 square array (wires 96-99)
tower detuned			- 37,73	35	330	130	8	**7,44**	added a load of X -999 on wire 41
FPenn10-NW-1s	101	1339	- 24,68	80	135	330	1	**7,53**	Added tower/4 elev.radials + 4 sq. + LOW DIPOLE
BPenn10-NW-1s	202	1496	- 36,85	40	35	230	3	**6,12**	Add.only the tower with NEW 32 radials on ground
tower detuned			- 35,00	30	330	134	24	**8,06**	added a load of X -999 on wire 41
GPenn10-NW-1s	199	1426	- 38,82	65	340	227	6	**6,84**	Added again the 4 square and reduced segments
tower detuned			- 37,69	35	335	131	9	**7,49**	added a TL 90 degrees short stub on wire 45
									Reduced to 9 pennants (deleted wires 25-28) and Increased segm. again to 112 each/ TL 90° short stub

This is the North-West Pennant in the southern group, located 62 meters from the TX tower, but exactly in line with it in the desired NW direction. The "NW-1s" is 24 meters from the tip of an elevated radial and 9 meters from the low dipole, and also only 3 meters from a vertical dipole of the 4-square array.

Thus, we see here at first the action of the 4-square on the Pennant, which reduces the front to back ratio by almost 30 dB; than the addition of the tower further deteriorates the situation but, in this case, detuning the TX antenna is successful, even keeping the elevated radials. It's a prove that the tower (in line with the desired direction) is electrically cancelled, whatever the radial system beneath it (see CPenn and DPenn rows above) and the pattern recovers its initial shape in both cases.

Unfortunately, not only the proximity of the low dipole - definitely removed - but also that of the 4-square have a prohibitive interaction. So, there is no reason to keep that Pennant in the group!





Azimuth Plot: worst case   Pennant NW-1s   Azimuth Plot: best case

NE-1n

Single PENNANT bearing North East from (wire 1 (X -3,9; Y +39,9) to > source wire 3 (X +4,7; Y +41,9)

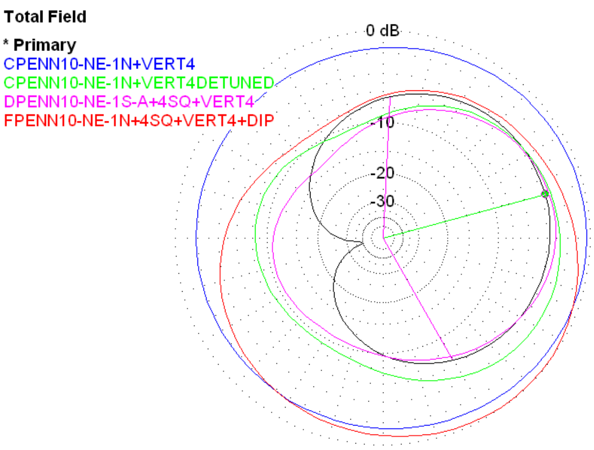
File	wires	Segm.	gain	TO	Bearing	BW	FB	RDF	Description notes
Primary trace APenn10-NE-1n	40	1120	- 35,29	30	75	147	36	**7,79**	Only the 10 Pennants - 112 segments each
EPenn10-NE-1n	44	1180	- 35,29	30	75	147	36	**7,79**	Added the 4 square mini-phased array (wires 41-44)
CPenn10-NE-1n	95	1249	- 32,01	70	85	330	1	**7,32**	Added top loaded tower with 4 elev.radials (in use)
tower detuned			- 31,41	65	90	330	1	**6,94**	added a load of X -999 on wire 41
DPenn10-NE-1n	99	1309	- 31,41	55	35	151	7	**8,00**	Added again the 4 square array (wires 96-99)
tower detuned			- 32,95	45	125	169	7	**6,99**	added a load of X -999 on wire 41
FPenn10-NE-1n	101	1339	- 31,70	55	135	188	8	**7,46**	Added tower/4 elev.radials + 4 sq. + LOW DIPOLE
BPenn10-NE-1n	202	1496	- 34,54	30	65	134	18	**8,11**	Add. only the tower with NEW 32 radials on ground
tower detuned			- 35,48	30	75	150	29	**7,73**	added a load of X -999 on wire 41
GPenn10-NE-1n	206	1436	- 34,46	30	60	135	17	**8,10**	Added again the 4 square and reduced segments
tower detuned			- 35,36	30	75	154	30	**7,66**	added a TL 90 degrees short stub on wire 45
HPenn9-NE-1n	199	1426	- 34,42	29	63	134	17	**8,11**	Reduced to 9 pennants (deleted wires 25-28) and
tower detuned			- 35,37	31	76	150	34	**7,73**	increased segm. again to 112 each/ TL 90° short stub

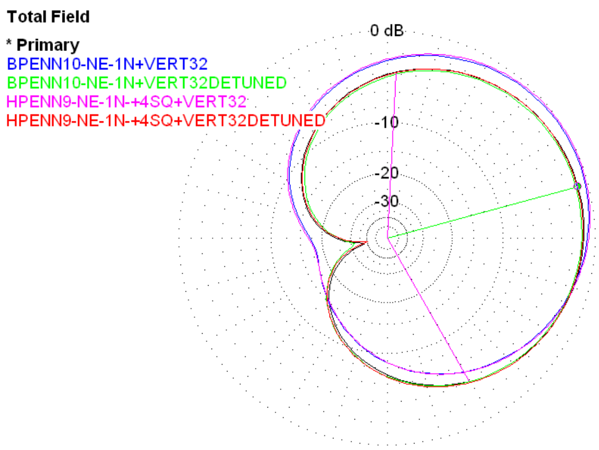
This is the North-East Pennant in the northern group, located 40 meters from the TX tower, 32 meters from an elevated radial (but parallel to it) and 23 from the tip of another one, thus getting a disruptive action from them.

The pattern looses completely its cardioid shape going into a high-angle lobe with very low directive characteristics; trying to detune the tower does not have any effect as the distortion comes from those radials first.

Curious enough, and I can't understand why (after checking and checking again) that small "positive" influence of the addition of the 4-square (95 meter distance) beyond the elevated radials (row DPenn).

In any case, after substituting the radial system and detuning the tower with a quarter wave short stub, the performance of this single Pennant approaches again that of a stand-alone!





Azimuth Plot: worst case   Pennant NE-1n   Azimuth Plot: best case

NE-1s

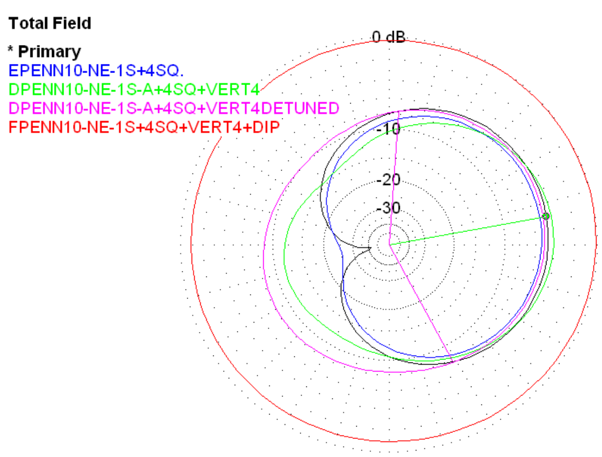
Single PENNANT bearing North East from wire 13 (X +18,2; Y -47,7) to > source wire 15 (X +26,8; Y -45,8)

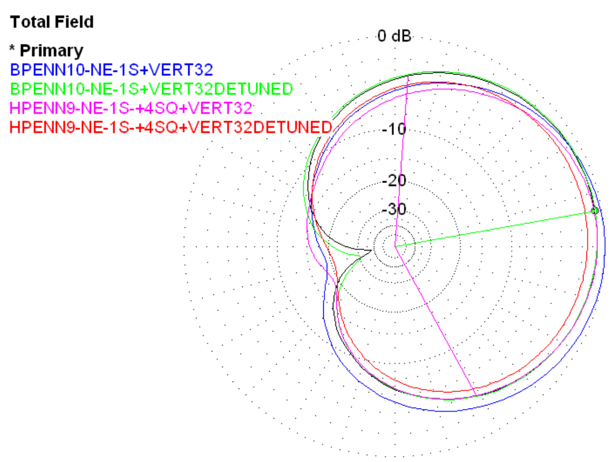
File	wires	segm.	gain	TO	Bearing	BW	FB	**RDF**	Description notes
Primary trace APenn10-NE-1s	40	1120	- 35,32	30	80	147	37	**7,80**	Only the 10 Pennants - 112 segments each
EPenn10-NE-1s	44	1180	- 36,04	30	80	141	20	**7,81**	Added the 4 square mini-phased array (wires 41-44)
CPenn10-NE-1s	95	1249	- 34,06	35	80	109	14	**8,41**	Added top loaded tower with 4 elev.radials (in use)
tower detuned			- 34,91	40	60	112	9	**7,94**	added a load of X -999 on wire 41
DPenn10-NE-1s	99	1309	- 34,79	40	85	108	8	**7,96**	Added again the 4 square array (wires 96-99)
tower detuned			- 35,67	55	75	161	4	**7,43**	added a load of X -999 on wire 41
FPenn10-NE-1s	101	1339	- 30,80	75	60	330	1	**6,97**	Added tower/4 elev.radials + 4 sq. + LOW DIPOLE
BPenn10-NE-1s	202	1496	- 34,77	30	90	134	18	**8,15**	Add.only the tower with NEW 32 radials on ground
tower detuned			- 35,30	30	75	148	30	**7,79**	added a load of X -999 on wire 41
GPenn10-NE-1s	206	1436	- 35,52	30	90	130	16	**8,12**	Added again the 4 square and reduced segments
tower detuned			- 35,92	30	80	139	22	**7,86**	added a TL 90 degrees short stub on wire 45
HPenn9-NE-1s	199	1426	- 35,39	30	86	127	15	**8,14**	Reduced to 9 pennants (deleted wires 25-28) and
tower detuned			- 36,21	32	80	146	19	**7,74**	increased segm. again to 112 each/ TL 90° short stub

This is the North-East Pennant in the southern group, located 52 meters from the TX tower, 16 meters from the tip of an elevated radial, but <u>only 8 meters from the low dipole and 5 meters from a 4-square</u> element.

If we examine carefully the table above, we see that the interactions are equally coming from the TX antenna with its elevated radials, and from the 4-square. Despite no elevated radials be too close to the Pennant, detuning the tower worsens the pattern especially in the TO angle (see row <u>CPenn</u> and <u>DPenn</u>), but here prevails the influence of the nearby 10 meters element of the 4-square.

At this point, the addition of the low dipole destroys completely every kind of directivity. After substituting the radial system and detuning the tower with a quarter wave short stub, the performance of this single Pennant approaches that of a stand-alone, but the interaction with the too close vertical dipole, even on the back, cannot be voided.





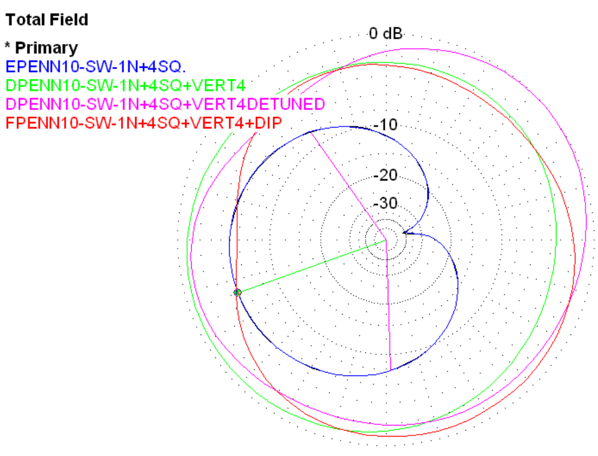
Azimuth Plot: worst case   Pennant NE-1s   Azimuth Plot: best case

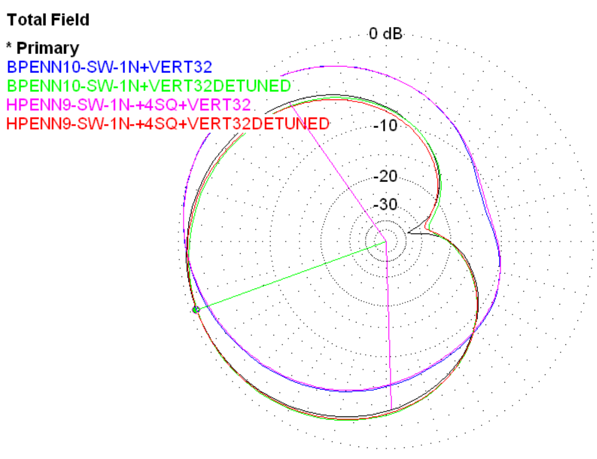
SW-1n **Single PENNANT bearing South West from wire 5 (X +13,2; Y +44,8) to > source wire 7 (X +4,8; Y +42,0)**									
File	wires	segm.	gain	TO	Bearing	BW	FB	**RDF**	Description notes
Primari trace APenn10-SW-1n	40	1120	- 35,29	30	250	147	37	**7,80**	Only the 10 Pennants - 112 segments each
EPenn10-SW-1n	44	1180	- 35,33	30	255	148	32	**7,76**	Added the 4 square mini-phased array (wires 41-44)
CPenn10-SW-1n	95	1249	- 29,95	65	330	169	4	**7,27**	Added top loaded tower with 4 elev.radials (in use)
tower detuned			- 34,60	60	280	313	3	**6,37**	added a load of X -999 on wire 41
DPenn10-SW-1n	99	1309	- 30,98	60	235	346	3	**6,53**	Added again the 4 square array (wires 96-99)
tower detuned			- 30,51	50	50	320	1	**6,13**	added a load of X -999 on wire 41
FPenn10-SW-1n	101	1339	- 31,21	60	160	295	2	**6,41**	Added tower/4 elev.radials + 4 sq. + LOW DIPOLE
BPenn10-SW-1n	202	1496	- 34,77	30	295	128	9	**7,95**	Add.only the tower with NEW 32 radials on ground
tower detuned			- 35,29	30	245	146	24	**7,81**	added a load of X -999 on wire 41
GPenn10-SW-1n	206	1436	- 34,74	30	295	129	9	**7,93**	Added again the 4 square and reduced segments
tower detuned			- 35,20	30	250	149	30	**7,72**	added a TL 90 degrees short stub on wire 45
HPenn9-SW-1n	199	1426	- 34,78	29	295	126	9	**7,98**	Reduced to 9 pennants (deleted wires 25-28) and
tower detuned			- 35,32	31	248	145	27	**7,83**	increased segm. again to 112 each/ TL 90° short stub

This is the South-West Pennant in the northern group, located 46 meters from the TX tower, 26 meters from the tip of an elevated radial and 40 from the tip of another.

As we see, the influence of the elevated radials, even at a reasonable distance as in this case, is terrible, and trying to detune the tower has no success. The 4-square, over 100 meters far, is not seen, and also the addition of the low dipole does not add anything worse to the already deteriorated pattern.

The lower part of the above table and the right plot confirm that the only stuff causing interaction to this Pennant is the radial system of the TX antenna. After substituting it, every detuning method, be it a loading reactance or a shorted quarter wave transmission line, is fully satisfactory.





Azimuth Plot: worst case — Pennant SW-1n — Azimuth Plot: best case

SW-1s

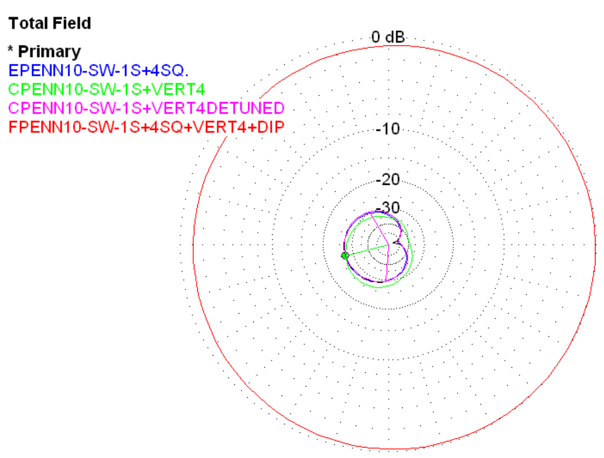
Single PENNANT bearing South West from wire 21 (X +35,6; Y -43,7) to > source wire 23 (X +27,0; Y -45,8)

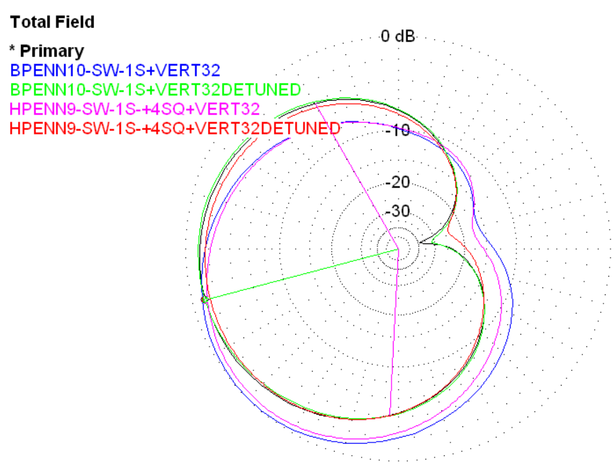
File	wires	segm.	gain	TO	Bearing	BW	FB	RDF	Description notes
Primary trace APenn10-SW-1s	40	1120	- 35,30	30	255	147	38	**7,80**	Only the 10 Pennants - 112 segments each
EPenn10-SW-1s	44	1180	- 35,46	30	255	142	26	**7,88**	Added the 4 square mini-phased array (wires 41-44)
CPenn10-SW-1s	95	1249	- 34,39	30	220	113	11	**8,41**	Added top loaded tower with 4 elev.radials (in use)
tower detuned			- 35,50	30	265	151	24	**7,69**	added a load of X -999 on wire 41
DPenn10-SW-1s	99	1309	- 34,60	30	225	112	13	**8,50**	Added again the 4 square array (wires 96-99)
tower detuned			- 35,67	30	260	146	20	**7,76**	added a load of X -999 on wire 41
FPenn10-SW-1s	101	1339	- 8,80	75	125	330	1	**7,21**	Added tower/4 elev.radials + 4 sq. + LOW DIPOLE
BPenn10-SW-1s	202	1496	- 34,21	30	225	121	13	**8,15**	Add.only the tower with NEW 32 radials on ground
tower detuned			- 35,23	30	265	148	27	**7,80**	added a load of X -999 on wire 41
GPenn10-SW-1s	206	1436	- 34,45	30	230	120	14	**8,12**	Added again the 4 square and reduced segments
tower detuned			- 34,92	30	260	135	19	**7,90**	added a TL 90 degrees short stub on wire 45
HPenn9-SW-1s	199	1426	- 34,61	29	224	119	12	**8,30**	Reduced to 9 pennants (deleted wires 25-28) and
tower detuned			- 35,73	30	249	151	22	**7,77**	increased segm. again to 112 each/ TL 90° short stub

This is the South-West Pennant in the southern group, located 56 meters from the TX tower, 17 meters from the tip of an elevated radial and 10 meters from the 4-square. The closeness of the 4-square reduces only mildly the FB ratio, and the addition of the TX antenna with its elevated radials is not disruptive as usual, letting a good shape of the pattern without raising the take-off angle; here detuning the tower is satisfactory even with the elevated radials.

But the low dipole is hanging from the same pole which supports the Pennant and the coupling is awful; the high currents induced in the dipole, and through it to a couple of elevated radials, cause a huge mess which deteriorates the pattern and the gain figures.

After removing the latter and substituting the radial system, we note that the results are almost the same that in the preceding case, that of the Pennant facing the same direction in the northern group. By comparing the two right plots we see the same detuning effect, just shift on opposite sides according to their relevant position towards the TX antenna.





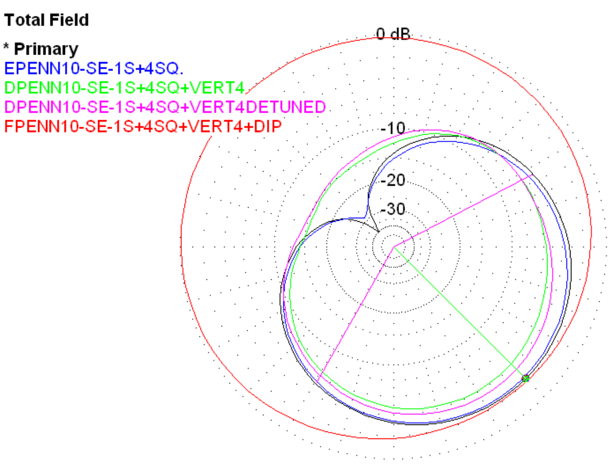
Azimuth Plot: worst case   Pennant SW-1s   Azimuth Plot: best case

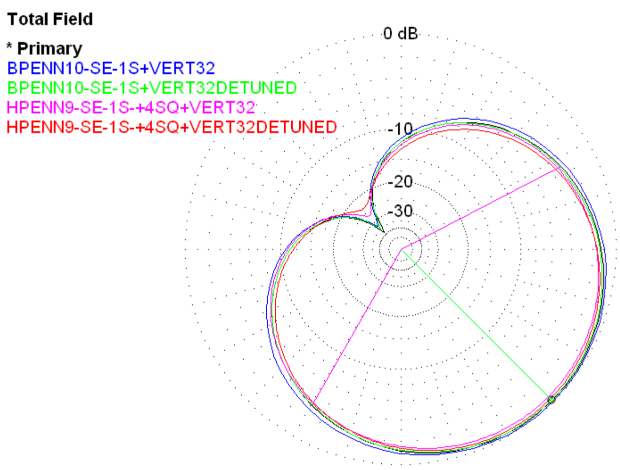
SE-1s **Single PENNANT bearing South East from wire 17 (X +21,0; y -39,0) to > source wire 19 (X +26,9; Y -45,7)**									
File	Wires	segm.	gain	TO	Bearing	BW	FB	**RDF**	Description notes
Primary trace APenn10-SE-1s	40	1120	- 35,42	30	135	147	38	**7,79**	Only the 10 Pennants - 112 segments each
EPenn10-SE-1s	44	1180	- 35,63	30	140	143	26	**7,85**	Added the 4 square mini-phased array (wires 41-44)
CPenn10-SE-1s	95	1249	- 36,69	25	145	154	11	**7,09**	Added top loaded tower with 4 elev.radials (in use)
tower detuned			- 36,87	25	145	159	12	**7,03**	added a load of X -999 on wire 41
DPenn10-SE-1s	99	1309	- 37,35	25	150	164	11	**6,89**	Added again the 4 square array (wires 96-99)
tower detuned			- 36,61	30	145	143	11	**7,40**	added a load of X -999 on wire 41
FPenn10-SE-1s	101	1339	- 33,23	75	290	330	2	**7,57**	Added tower/4 elev.radials + 4 sq. + LOW DIPOLE
BPenn10-SE-1s	202	1496	- 35,32	35	135	155	33	**7,66**	Add.only the tower with NEW 32 radials on ground
tower detuned			- 35,48	30	135	147	35	**7,79**	added a load of X -999 on wire 41
GPenn10-SE-1s	206	1436	- 35,57	30	140	146	30	**7,79**	Added again the 4 square and reduced segments
tower detuned			- 35,32	30	140	140	24	**7,94**	added a TL 90 degrees short stub on wire 45
HPenn9-SE-1s	199	1426	- 35,86	33	138	151	26	**7,66**	Reduced to 9 pennants (deleted wires 25-28) and
tower detuned			- 35,62	31	138	142	23	**7,88**	increased segm. again to 112 each/ TL 90° short stub

This is the South-East Pennant in the southern group (the only one in that direction), located 45 meters from the TX tower, 11 meters from the tip of an elevated radial and less than 2 meters from the low dipole.

The interaction from the 4-square and the TX antenna with elevated radials reduces the FB ratio in the Pennant but keeps a reasonably good pattern at low elevation angles.

As usual the addition of the low dipole destroys everything. Tower detuning here does not have any effect, neither in the case of elevated radials, nor in the case of on ground radials, as it is on the back of the fired direction. In any case, it is confirmed again that substituting the TX radial system is a must!





Azimuth Plot: worst case Pennant SE-1s Azimuth Plot: best case

SW-2br

Two Pennants in BROADSIDE configuration bearing South West (sources on wire 7 / phase 0 + wire 23 / phase 0)

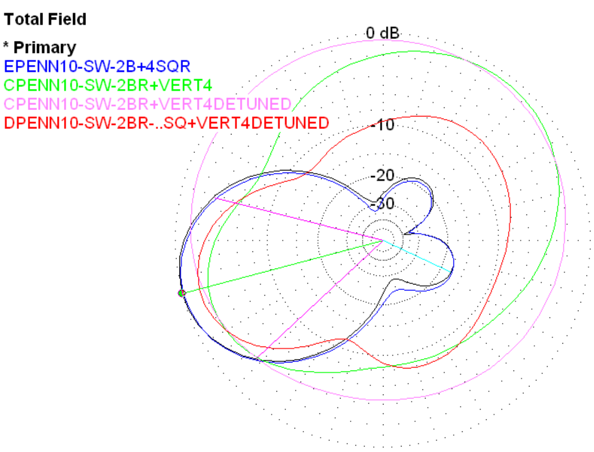
File	wires	Segm.	gain	TO	Bearing	BW	FB	**RDF**	Description notes
Primary trace APenn10-SW-2br	40	1120	- 32,29	30	255	57	38	**10,82**	Only the 10 Pennants - 112 segments each
EPenn10-SW-2br	44	1180	- 32,39	30	255	57	35	**10,79**	Added the 4 square mini-phased array (wires 41-44)
CPenn10-SW-2br	95	1249	- 32,88	40	40	113	3	**7,21**	Added top loaded tower with 4 elev.radials (in use)
tower detuned			- 32,89	70	355	278	4	**7,28**	added a load of X -999 on wire 41
DPenn10-SW-2br	99	1309	- 32,90	45	30	143	2	**6,41**	Added again the 4 square array (wires 96-99)
tower detuned			- 33,80	30	255	53	6	**8,45**	added a load of X -999 on wire 41
FPenn10-SW-2br	101	1339	- 12,26	75	125	330	1	**7,10**	Added tower/4 elev.radials + 4 sq. + LOW DIPOLE
BPenn10-SW-2br	202	1496	- 32,29	30	255	64	16	**9,99**	Add.only the tower with NEW 32 radials on ground
tower detuned			- 32,44	30	255	57	29	**10,83**	added a load of X -999 on wire 41
GPenn10-SW-2br	206	1436	- 32,47	35	255	64	15	**9,82**	Added again the 4 square and reduced segments
tower detuned			- 32,01	30	255	58	23	**10,61**	added a TL 90 degrees short stub on wire 45
HPenn9-SW-2br	199	1426	- 32,66	35	254	64	15	**9,96**	Reduced to 9 pennants (deleted wires 25-28) and
tower detuned			- 32,55	32	255	59	23	**10,47**	increased segm. again to 112 each/ TL 90° short stub

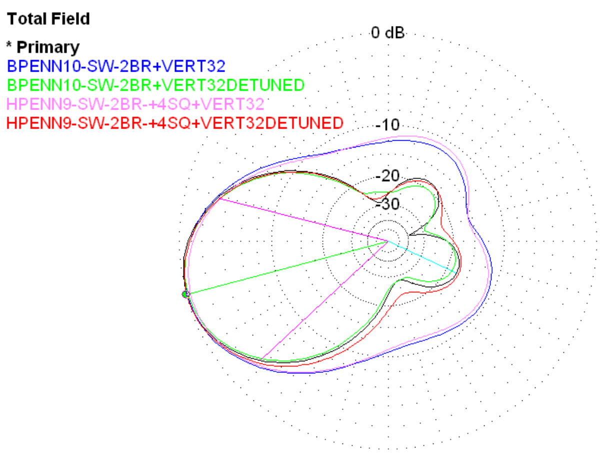
These are the two Pennants SW-1n and SW-1s fed in phase through two equal lengths of buried RG213 cables converging to a central W2FMI-2:1-HDU50 Un-Un transmission line transformer.

There seems to be no coupling effect from the 4-square alone (row EPenn) but, after adding the tower with the elevated radials, a relevant interaction arises, especially with the detuned option: the patterns get a random shape both in azimuth and elevation.

As in the case of the SW-1s alone, the presence of the low dipole is so destroying, that I did not add its trace on the left-hand plot (its trace on the outer ring had reduced too much the others).

After removing the latter and substituting the radial system, we bring back the broadside to work as desired and detuning the tower improves further the pattern to the ideal one. And, again the 4-square has only a minimal effect on the FB ratio.





Azimuth Plot: worst case — Pennant SW-2br — Azimuth Plot: best case

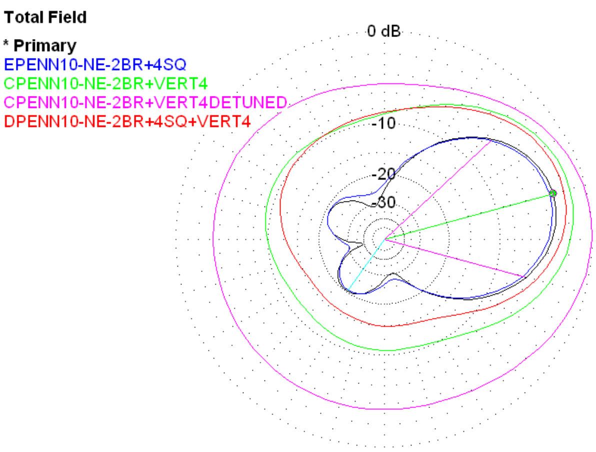
NE-2br Two Pennants in BROADSIDE configuration bearing North East (sources on wire 3 / phase 0 + wire 15 / phase 0)									
File	wires	segm.	gain	TO	Bearing	BW	FB	**RDF**	Description notes
Primary trace APenn10-NE-2br	40	1120	- 32,30	30	75	58	36	**10,78**	Only the 10 Pennants - 112 segments each
EPenn10-NE-2br	44	1180	- 32,65	30	75	58	27	**10,66**	Added the 4 square mini-phased array (wires 41-44)
CPenn10-NE-2br	95	1249	- 30,67	40	75	76	10	**8,86**	Added top loaded tower with 4 elev.radials (in use)
tower detuned			- 29,33	50	85	116	3	**7,58**	added a load of X -999 on wire 41
DPenn10-NE-2br	99	1309	- 31,24	35	70	71	13	**9,19**	Added again the 4 square array (wires 96-99)
tower detuned			- 31,83	40	75	73	8	**8,78**	added a load of X -999 on wire 41
FPenn10-NE-2br	101	1339	- 23,76	70	145	246	4	**8,34**	Added tower/4 elev.radials + 4 sq. + LOW DIPOLE
BPenn10-NE-2br	202	1496	- 31,72	30	75	60	19	**10,64**	Add.only the tower with NEW 32 radials on ground
tower detuned			- 32,53	30	75	57	32	**10,80**	added a load of X -999 on wire 41
GPenn10-NE-2br	206	1436	- 32,01	30	75	60	18	**10,58**	Added again the 4 square and reduced segments
tower detuned			- 32,63	30	75	58	29	**10,68**	added a TL 90 degrees short stub on wire 45
HPenn9-NE-2br	199	1426	- 32,07	30	76	60	18	**10,57**	Reduced to 9 pennants (deleted wires 25-28) and
tower detuned			- 32,77	32	76	59	24	**10,68**	increased segm. again to 112 each/ TL 90° short stub

These are the two Pennants NE-1n and NE-1s fed in phase through two equal lengths of buried RG213 cables converging to a central W2FMI-2:1-HDU50 Un-Un transmission line transformer.

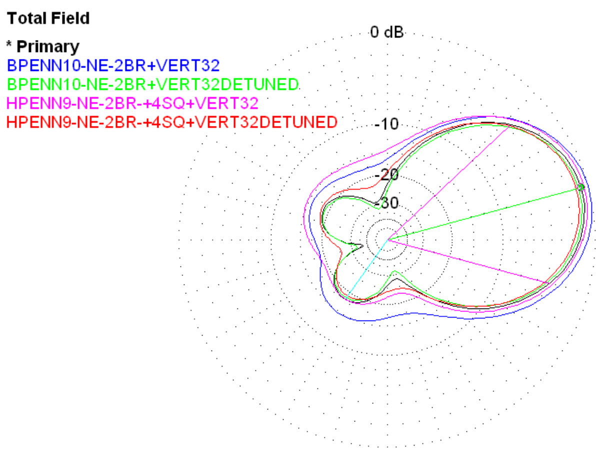
Here we see (row CPenn) that the presence of the TX antenna with elevated radials ruins as usual the pattern and the RDF, and detuning the tower is even worse (that happens because we null out the tower, which acts as reflector in this set-up, and leave the coupling from the high radials), but adding again the 4-square we recover a better situation (row DPenn) and it's preferred with no tower detuning.

As in the preceding case, the low dipole is so destroying, that I did not add its trace on the left-hand plot (its trace on the outer ring had reduced too much the others).

After removing the dipole and substituting the radial system, we bring back the broadside to get a pattern as desired. Nothing changes with the addition of the 4-square, and detuning the tower improves mildly only the FB ratio. Note that T.O. angle, bearing, BW and RDF are practically unaltered.



Azimuth Plot: worst case



Pennant NE-2br

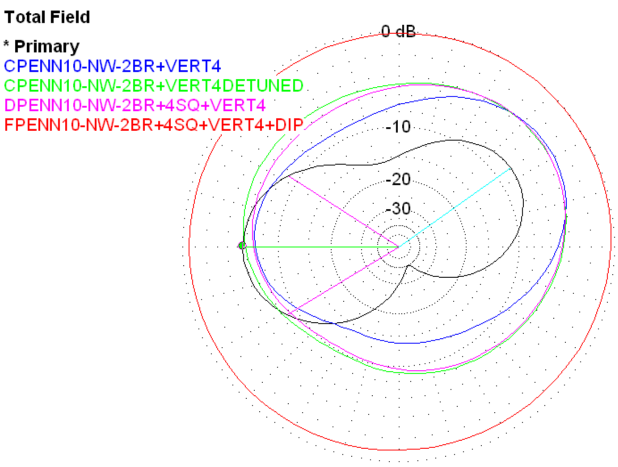
Azimuth Plot: best case

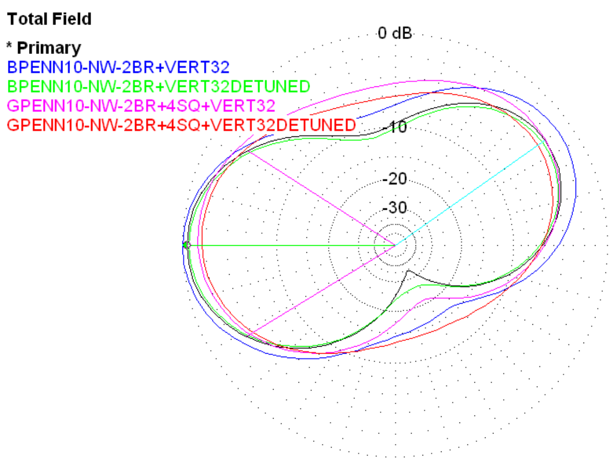
NW-2br **Two Pennants in BROADSIDE configuration bearing North West (source on wire 11 / phase 0 + wire 27 / phase 0)**									
File	wires	segm.	gain	TO	Bearing	BW	FB	**RDF**	Description notes
Primary trace APenn10-NW-2br	40	1120	- 34,88	40	270	64	6	**8,82**	Only the 10 Pennants - 112 segments each
EPenn10-NW-2br	44	1180	- 36,09	50	275	84	5	**8,35**	Added the 4 square mini-phased array (wires 41-44)
CPenn10-NW-2br	95	1249	- 32,41	45	55	87	8	**8,52**	Added top loaded tower with 4 elev.radials (in use)
tower detuned			- 32,78	60	50	221	5	**8,16**	added a load of X -999 on wire 41
DPenn10-NW-2br	99	1309	- 32,70	55	50	194	6	**8,06**	Added again the 4 square array (wires 96-99)
tower detuned			- 33,26	70	40	327	3	**7,85**	added a load of X -999 on wire 41
FPenn10-NW-2br	101	1339	- 29,28	75	40	330	1	**7,08**	Added tower/4 elev.radials + 4 sq. + LOW DIPOLE
BPenn10-NW-2br	202	1496	- 34,52	40	270	68	4	**8,17**	Add.only the tower with NEW 32 radials on ground
tower detuned			- 35,06	40	270	64	6	**8,86**	added a load of X -999 on wire 41
GPenn10-NW-2br	199	1426	- 35,76	50	275	90	6	**7,97**	Added again the 4 square and reduced segments
tower detuned			- 36,13	50	275	83	5	**8,38**	added a TL 90 degrees short stub on wire 45
									Reduced to 9 pennants (deleted wires 25-28) and increased segm. again to 112 each/ TL 90° short stub

Here are the results that could be achieved by trying to feed in phase the two Pennants NW-1n and NW-1s, taking use of the ready switching and cabling system of the preceding broadsides.

These Pennants, both facing North-West, are not perpendicular to the plane containing them, but staggered and thus, at a distant point lying on a line perpendicular to the axis of the antenna, the fields cannot add up in phase as should in a broadside configuration. The pattern arising from this firing is squeezed and bidirectional into South-West and North-East with a well pronounced null towards South-East (as it should be).

Of course, all the next runs look like the ones with the single pertinent Pennants but, after all, this should be a useless set-up as the resulting two maximum bearings are better gotten with the unidirectional pattern of the other (SW-2br and NE-2br) broadside configurations, and whose RDF is clearly outstanding. So, this configuration is useless!





Azimuth Plot: worst case Pennant NW-2br Azimuth Plot: best case

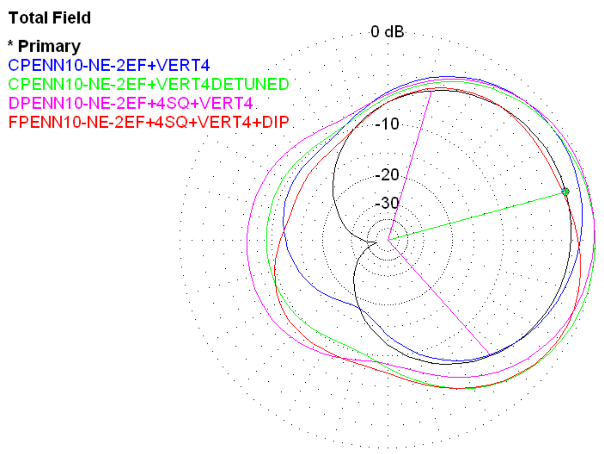
NE-2ef
Two Pennants in ENDFIRE configuration bearing North East (source wires: 3(0°) + 31(-90°))

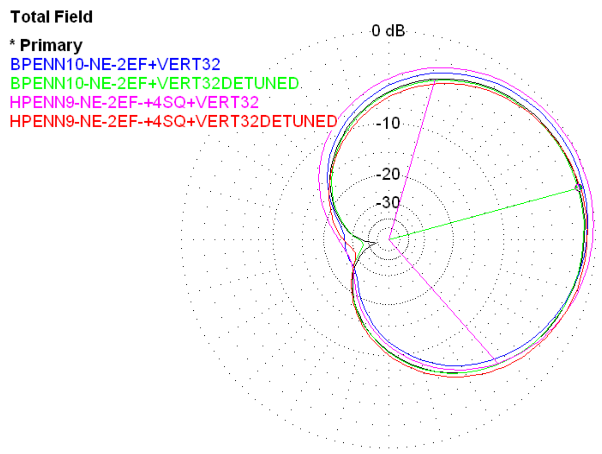
File	wires	segm.	gain	TO	Bearing	BW	FB	**RDF**	Description notes
Primary trace APenn10-NE-2ef	40	1120	- 32,60	30	75	122	46	**8,85**	Only the 10 Pennants - 112 segments each
EPenn10-NE-2ef	44	1180	- 32,59	30	75	121	47	**8,86**	Added the 4 square mini-phased array (wires 41-44)
CPenn10-NE-2ef	95	1249	- 31,22	30	65	109	14	**8,90**	Added top loaded tower with 4 elev.radials (in use)
tower detuned			- 30,61	35	65	122	9	**7,93**	added a load of X -999 on wire 41
DPenn10-NE-2ef	99	1309	- 30,63	35	80	115	7	**7,59**	Added again the 4 square array (wires 96-99)
tower detuned			- 31,08	35	95	89	9	**8,47**	added a load of X -999 on wire 41
FPenn10-NE-2ef	101	1339	- 31,32	35	115	125	12	**8,38**	Added tower/4 elev.radials + 4 sq. + LOW DIPOLE
BPenn10-NE-2ef	202	1496	- 32,23	30	70	116	26	**9,07**	Add.only the tower with NEW 32 radials on ground
tower detuned			- 32,69	30	80	112	35	**8,83**	added a load of X -999 on wire 41
GPenn10-NE-2ef	206	1436	- 32,18	30	70	116	25	**9,04**	Added again the 4 square and reduced segments
tower detuned			- 32,53	30	80	122	32	**8,85**	added a TL 90 degrees short stub on wire 45
HPenn9-NE-2ef	199	1426	- 31,79	28	74	118	26	**8,94**	Reduced to 9 pennants (deleted wires 25-28) and
tower detuned			- 32,46	30	84	119	27	**8,83**	increased segm. again to 112 each/ TL 90° short stub

Aimed at the research of any possible improvement in the North-East direction (which means Asia and Oceania for me), I tried to fit a new Pennant in the north-eastern corner of my property, to be used only in an end-fed configuration with the existing NE-1n. It's going to be located 55 meters from the TX antenna and 20 meters from the tip of the nearest elevated radial, but only 30 meters from the existing NE-1n Pennant, in line with it and thus that's the only available possibility for an end-fed configuration. (…anyway, as a next work I will try to optimize for other available separations and to sweep through the best phasing delay).

Even without a quarter wave physical distance, this endfire design results to work as desired with a very good cardioid pattern, after removing the elevated radials.

Detuning the tower has only a marginal effect on the azimuthal lobe and decreases a little bit the RDF, so it could be better to keep that massive reflector on the back.



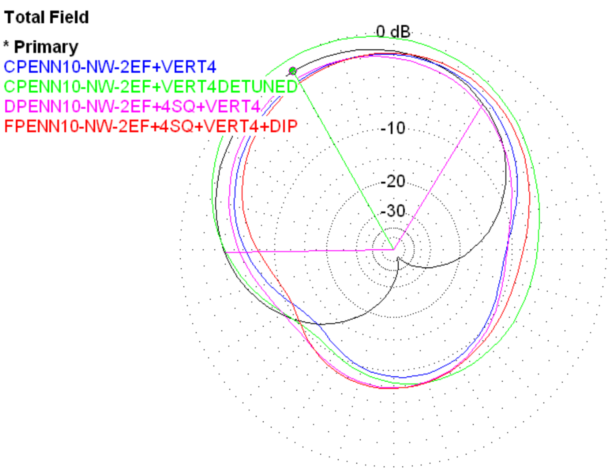


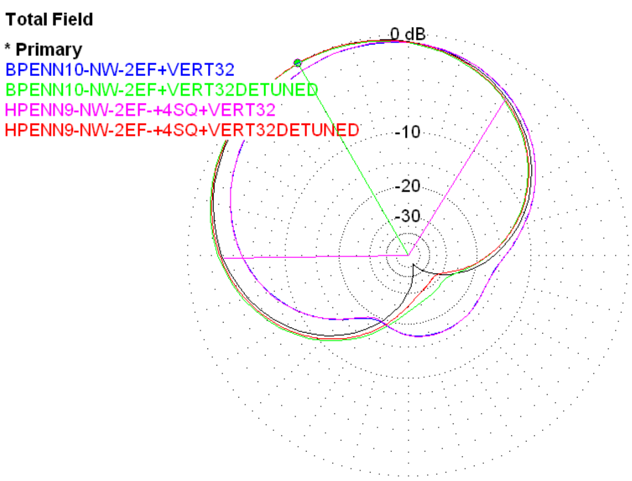
Azimuth Plot: worst case Pennant NE-2ef Azimuth Plot: best case

NW-2ef Two Pennants in ENDFIRE configuration bearing North West (source wires: 11(-90°) + 35(0°))									
File	wires	segm.	gain	TO	Bearing	BW	FB	**RDF**	Description notes
Primary trace APenn10-NW-2ef	40	1120	- 32,33	30	330	123	53	**8,87**	Only the 10 Pennants - 112 segments each
EPenn10-NW-2ef	44	1180	- 32,32	30	330	123	55	**8,88**	Added the 4 square mini-phased array (wires 41-44)
CPenn10-NW-2ef	95	1249	- 33,07	35	350	122	7	**7,75**	Added top loaded tower with 4 elev.radials (in use)
tower detuned			- 31,30	40	335	123	8	**7,82**	added a load of X -999 on wire 41
DPenn10-NW-2ef	99	1309	- 32,99	40	335	118	7	**7,72**	Added again the 4 square array (wires 96-99)
tower detuned			- 32,06	35	335	120	12	**8,31**	added a load of X -999 on wire 41
FPenn10-NW-2ef	101	1339	- 33,08	40	355	123	6	**7,65**	Added tower/4 elev.radials + 4 sq. + LOW DIPOLE
BPenn10-NW-2ef	202	1496	- 32,81	30	345	117	16	**8,96**	Add.only the tower with NEW 32 radials on ground
tower detuned			- 32,32	30	330	123	27	**8,87**	added a load of X -999 on wire 41
GPenn10-NW-2ef	206	1436	- 32,74	30	345	117	16	**8,95**	Added again the 4 square and reduced segments
tower detuned			- 32,24	30	330	123	31	**8,90**	added a TL 90 degrees short stub on wire 45
HPenn9-NW-2ef	199	1426	- 32,80	29	346	117	16	**8,95**	Reduced to 9 pennants (deleted wires 25-28) and
tower detuned			- 32,32	30	330	123	31	**8,89**	increased segm. again to 112 each/ TL 90° short stub

I examined also all the ways to get every possible improvement with the Pennants in the North-West direction (which means North America, over 90% of all my Topband QSO's). We have already seen that a broadside configuration does not work, and there is also a problem with the tower mainly in front of all the antennas facing that direction.
Being end-fire the only possible solution, I put a new Pennant exactly in line with the NW-1n at the optimum distance of 41 meters and fed with 90 degrees phase difference. The resulting pattern is as it should be (see the original K6SE design) with a FB ratio over 50 dB and gain, beamwidth, and RDF not as good as in the broadside, but better than in a single element.

The new Pennant is at a distance of 27 meters from the TX antenna and, of course, the "on ground radials" and detuning tower is a must, but still not enough to recover that deep null on the back.





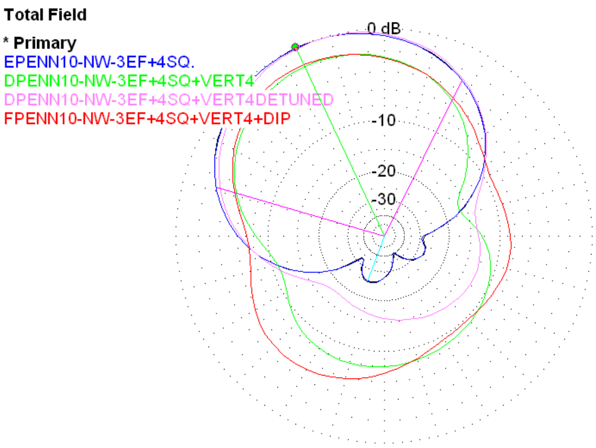
Azimuth Plot: worst case   Pennant NW-2ef   Azimuth Plot: best case

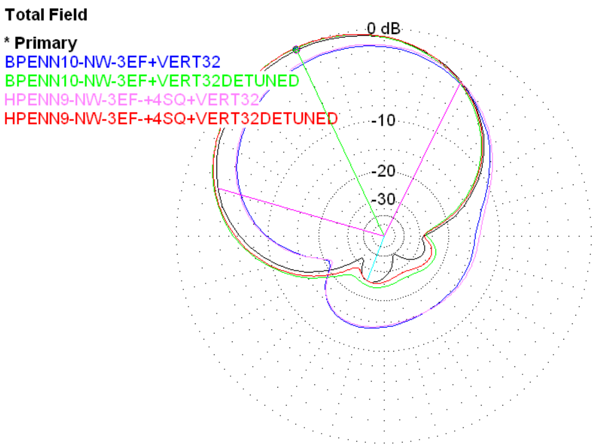
NW-3ef **Three Pennants in ENDFIRE config. bearing North West (source wires: 11(-90°) + 35(0°) + 39(+90°))**									
File	wires	segm.	gain	TO	Bearing	BW	FB	**RDF**	Description notes
Primary trace APenn10-NW-3ef	40	1120	- 31,05	25	335	100	38	**10,15**	Only the 10 Pennants - 112 segments each
EPenn10-NW-3ef	44	1180	- 31,07	25	335	100	40	**10,14**	Added the 4 square mini-phased array (wires 41-44)
CPenn10-NW-3ef	95	1249	- 33,20	30	340	93	6	**8,45**	Added top loaded tower with 4 elev.radials (in use)
tower detuned			- 30,85	30	335	97	13	**9,39**	added a load of X -999 on wire 41
DPenn10-NW-3ef	99	1309	- 32,85	30	335	94	7	**8,46**	Added again the 4 square array (wires 96-99)
tower detuned			- 31,10	30	340	99	15	**9,50**	added a load of X -999 on wire 41
FPenn10-NW-3ef	101	1339	- 32,62	35	330	93	8	**7,32**	Added tower/4 elev.radials + 4 sq. + LOW DIPOLE
BPenn10-NW-3ef	202	1496	- 32,25	25	345	100	13	**9,76**	Add.only the tower with NEW 32 radials on ground
tower detuned			- 30,89	25	335	100	25	**10,11**	added a load of X -999 on wire 41
GPenn10-NW-3ef	206	1436	- 32,22	30	345	101	13	**9,71**	Added again the 4 square and reduced segments
tower detuned			- 30,93	25	335	101	28	**10,13**	added a TL 90 degrees short stub on wire 45
HPenn9-NW-3ef	199	1426	- 32,13	28	347	101	14	**9,76**	Reduced to 9 pennants (deleted wires 25-28) and
tower detuned			- 30,88	27	334	100	28	**10,15**	increased segm. again to 112 each/ TL 90° short stub

This is a meaningful upgrade of the North-West Pennants End-Fire arrangement with the addition of a third element on the back. The front element is the NW1n as in the two-element version, at a quarter-wavelength distance, and fed with a -90 degrees phasing; the back element should be put also in line with the others, at a distance of 0,25 wavelengths and a +90 degrees phasing, but that should have gone on the nearby public road! So, this new Pennant is located just on the fence, at a distance of 31 meters, rather than the ideal required 41 meters.

Nevertheless, the resulting pattern is very good, with a restrained beamwidth at a low take-off angle and a respectable front to back ratio (despite two small lobs) but, most important, the RDF rises to a value reachable only with a broadside configuration.

The new Pennant is far enough from all the other stuff but, of course, it's still better to change the radial system and detune the tower, even if in this case the interactions were not so disruptive as in most others.





Azimuth Plot: worst case Pennant NW-3ef Azimuth Plot: best case

Switching the Four-Square mini-phased vertical array.

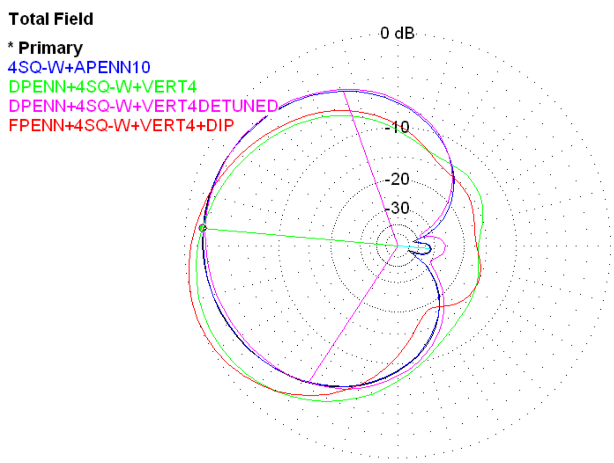
After analyzing all the Pennants options, which was the purpose of this work, I managed the same runs by switching directions - and thus changing the source wires and phases on the existing 4-square - whose closest elements are located at 54 meters from the TX antenna and 11 meters from the low dipole.

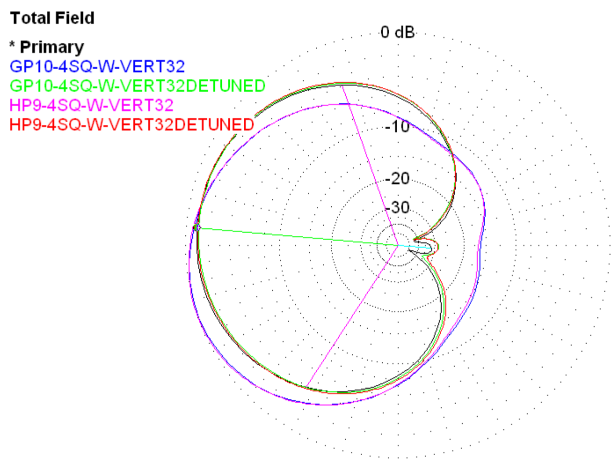
At first, we note that there is no reciprocity in the interactions with the Pennants. In all cases, there is no significative change by adding all the 10 Pennants (second row EPenn4SQ); and remember that, within 10, there was a Pennant vertical wire at a 3 meters distance from a 4-square element (see NW-1s) which was causing a 30 dB FB deterioration on the Pennant itself. No coupling at all on the vertical dipole. This is confirmed by comparing the rows GP10-4SQ with the HP9-4SQ below.

Then, we see also that there is no interaction with the elevated radials, and the tower detuning effect is absolutely the same, either with them, or with the on-ground radials; nulling out the tower is noteworthy only in the West and North directions.

Interesting also the behaviour of the low dipole whose coupling effects only when the 4-square is switched to South, towards its opposite direction. Is that depending by the phasing at zero degrees of the nearest back elements?

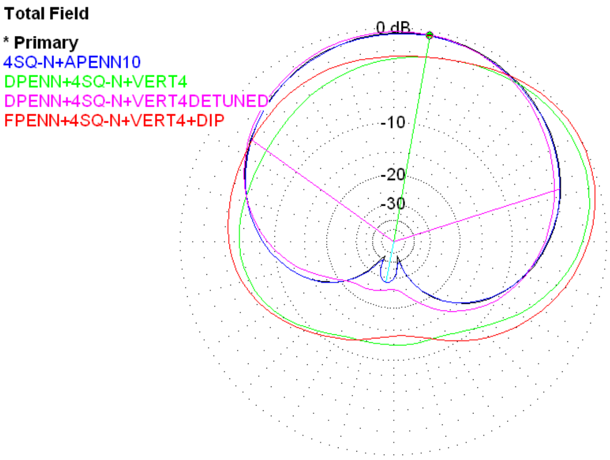
4sq-West	Wire 1:X+15,1;Y-52,1; wire 2:X+27,8 Y-53,6; wire 3: X+13,0 Y-65,0; wire 4: X+25,7 Y-66,5 Sources on wires: 1 (-155) + 2 (0) + 3 (-155) + 4 (0)								
File	wires	segm	gain	TO	Bearing	BW	FB	**RDF**	Description notes
4square-W	4	60	- 5,83	22	278	128	33	**9,39**	Only the original 4 square array in use
EPenn4SQ-W	44	1180	- 5,91	20	275	128	30	**9,36**	Added the 10 Pennants
DPenn4SQ-W	99	1309	- 4,96	20	250	98	14	**9,77**	Add the top loaded tower with 4 elev.radials (in use)
tower detuned			- 6,02	20	285	133	26	**9,27**	added a load of X -999 on wire 41
FPenn4SQ-W	101	1339	- 4,37	25	250	90	16	**9,96**	Added tower/4 el.radials + Pennants + LOW DIPOLE
GP10-4SQ-W	206	1436	- 5,03	25	255	104	15	**9,70**	Add 10 pennants + tower with 32 radials on ground
tower detuned			- 5,97	20	280	132	28	**9,27**	added a TL 90 degrees short stub on wire 45
HP9-4SQ-W	199	1426	- 4,96	23	253	103	15	**9,74**	Reduced the pennants to 9 and increased segments
tower detuned			- 5,91	22	282	133	28	**9,30**	again to 112 each/ TL 90° short stub on wire 41

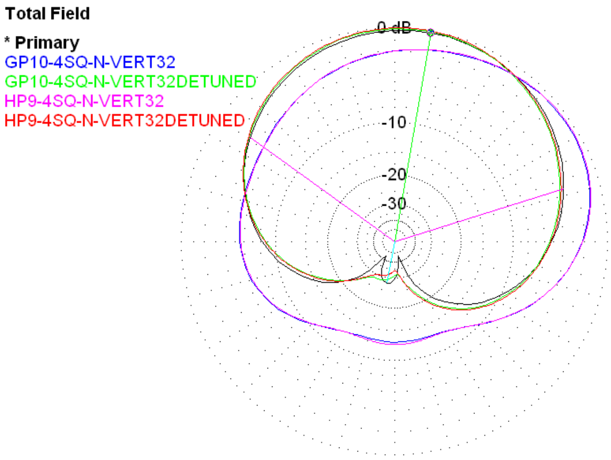




Azimuth Plot: worst case 4-Square: beaming West Azimuth Plot: best case

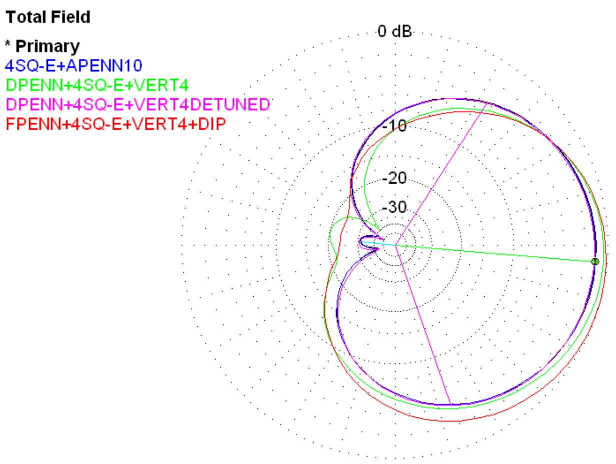
4sq-North	Sources on wires: 1 (-155) + 2 (-155) + 3 (0) + 4 (0)								
File	wires	segments	gain	TO	Bearing	BW	FB	**RDF**	Description notes
4square-N	4	60	- 5,77	22	10	128	29	**9,42**	Only the original 4 square array in use
EPenn4SQ-N	44	1180	- 5,85	20	10	127	28	**9,40**	Added the 10 Pennants
DPenn4SQ-N	99	1309	- 5,95	20	60	120	7	**8,66**	Add the top loaded tower with 4 elev.radials (in use)
tower detuned			- 5,71	20	5	120	25	**9,54**	added a load of X -999 on wire 41
FPenn4SQ-N	101	1339	- 5,42	25	60	143	7	**7,56**	Added tower/4 el.radials + Pennants + LOW DIPOLE
GP10-4SQ-N	206	1436	- 6,02	25	55	129	8	**8,62**	Add 10 pennants + tower with 32 radials on ground
tower detuned			- 5,70	20	5	122	30	**9,52**	added a TL 90 degrees short stub on wire 45
HP9-4SQ-N	199	1426	- 5,97	23	56	128	8	**8,63**	Reduced the pennants to 9 and increased segments
tower detuned			- 5,65	22	7	123	33	**9,54**	again to 112 each/ TL 90° short stub on wire 41

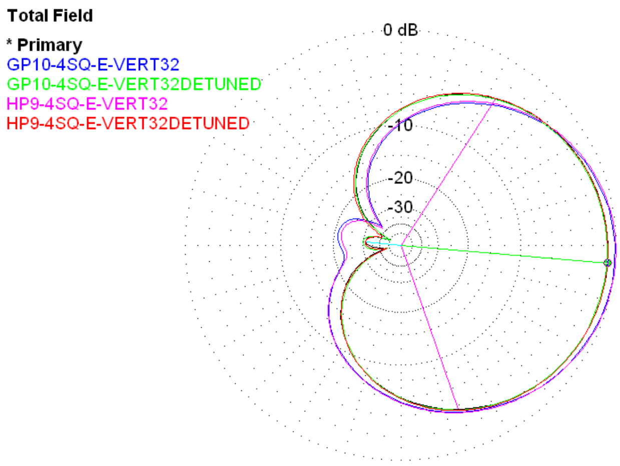




Azimuth Plot: worst case — 4-Square: beaming North — Azimuth Plot: best case

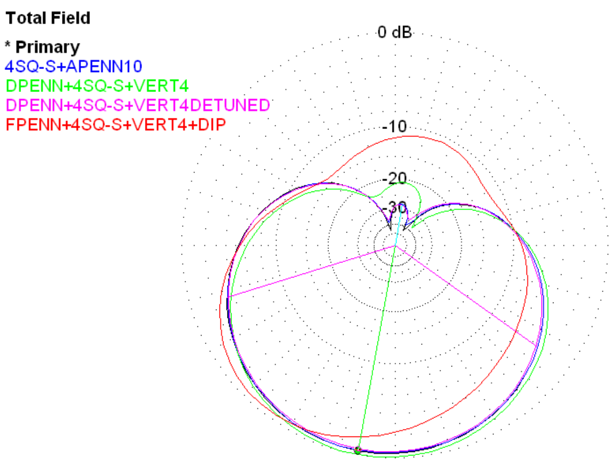
4sq-East	Sources on wires: 1 (0) + 2 (-155) + 3 (0) + 4 (-155)								
File	wires	segments	gain	TO	Bearing	BW	FB	**RDF**	Description notes
4square-E	4	60	- 5,83	22	98	128	33	**9,39**	Only the original 4 square array in use
EPenn4SQ-E	44	1180	- 5,90	20	95	128	30	**9,37**	Added the 10 Pennants
DPenn4SQ-E	99	1309	- 5,23	20	95	113	20	**9,70**	Add the top loaded tower with 4 elev.radials (in use)
tower detuned			- 5,98	20	100	130	30	**9,34**	added a load of X -999 on wire 41
FPenn4SQ-E	101	1339	- 4,91	20	105	119	23	**9,39**	Added tower/4 el.radials + Pennants + LOW DIPOLE
GP10-4SQ-E	206	1436	- 5,30	20	95	114	21	**9,65**	Add 10 pennants + tower with 32 radials on ground
tower detuned			- 5,93	20	100	129	30	**9,34**	added a TL 90 degrees short stub on wire 45
HP9-4SQ-E	199	1426	- 5,24	22	97	115	22	**9,68**	Reduced the pennants to 9 and increased segments
tower detuned			- 5,88	22	99	130	31	**9,36**	again to 112 each/ TL 90° short stub on wire 41

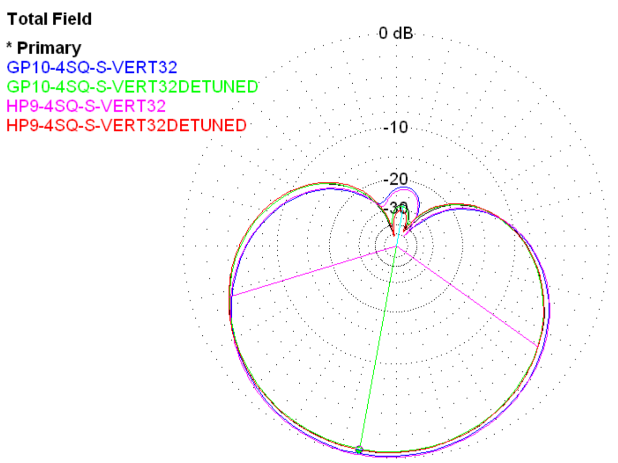




Azimuth Plot: worst case 4-Square: beaming East Azimuth Plot: best case

4sq-South	Sources on wires: 1 (0) + 2 (0) + 3 (-155) + 4 (-155)							
File	wires	segm.	gain	TO	Bearing	BW	FB	**RDF**	Description notes
4square-S	4	60	- 5,77	22	190	128	29	**9,42**	Only the original 4 square array in use
EPenn4SQ-S	44	1180	- 5,84	20	190	127	28	**9,40**	Added the 10 Pennants
DPenn4SQ-S	99	1309	- 5,47	20	190	122	21	**9,63**	Add the top loaded tower with 4 elev.radials (in use)
tower detuned			- 5,94	20	190	127	28	**9,42**	added a load of X -999 on wire 41
FPenn4SQ-S	101	1339	- 5,89	25	220	94	11	**8,78**	Added tower/4 el.radials + Pennants + LOW DIPOLE
GP10-4SQ-S	206	1436	- 5,49	20	190	124	22	**9,56**	Add 10 pennants + tower with 32 radials on ground
tower detuned			- 5,87	20	190	127	28	**9,40**	added a TL 90 degrees short stub on wire 45
HP9-4SQ-S	199	1426	- 5,41	22	190	124	23	**9,60**	Reduced the pennants to 9 and increased segments
tower detuned			- 5,81	22	189	128	30	**9,43**	again to 112 each/ TL 90° short stub on wire 41





Azimuth Plot: worst case 4-Square: beaming South Azimuth Plot: best case

Summary

Let me summarize the main observations arising from these analysis, all performed on 160 meters:

- The Pennants can be put together in groups and fed by switching the secondary winding of a common transformer on both wires, provided this is done on the apex opposite to the vertical wire (point fed); in this way no interaction among them or with other nearby Pennants.
- When a Pennant vertical wire (about 4 meters length) is near a vertical element of the 4-Square array (10 meters length), the Pennant is severely influenced, but the contrary is not true (i.e. the 4-Square does not see anything).
- Elevated quarter-wave radials could be a good solution for a TX vertical antenna, when in transmission (in the last 10 years I always worked all what I heard), but during reception, their interactions with receiving antennas are disruptive.
- I thought it could be safe enough to keep any kind of receiving antenna just out of the quarter-wavelengths radials, i.e. at least something more than 40 meters from the shunt-fed tower. That could be done with an "on ground radial system", but NOT with elevated radials.
- A considerable part of a Pennant antenna (but also of a Flag or a K9AY loop) is made up of sloping or almost horizontal wires, which happen to be mostly at the same height of the elevated resonant radials and the coupling effect takes place at as far as 40 meters from them, especially if they are parallel to each other. The interactions not only reduce the front to back ratio but deteriorate completely the pattern shape losing any directivity and rising, sometimes considerably, the take-off angle.
- By lowering the quarter-wave radials to the ground level (actually at 20 cm. in Eznec) all these interactions disappear.
- With elevated radials, any attempt to detune the transmitting tower has no effect; sometimes it is worse, as it cancels a fat reflector but leaves the mess of resonant conflicting wires.
- After lowering the radials to ground, detuning the TX antenna is always successful; the tower is electrically cancelled and the pattern of any nearby receiving antenna recovers its original shape. Of course, if the tower is on the back of the desired direction it could act as a useful reflector, so it is a good idea to arrange a switching option for the detuning stub.
- The low dipole could be useful on some occasions due to its very high take-off angle, but it should be placed far enough (at least half wavelength) from any Pennant or elevated radial; most of its length happens to be at about their same height and the huge coupling has a disruptive effect on the Pennants.
- The 4-Square mini-phased vertical array is the least subject to interactions. It is made up of vertical self-supporting dipoles, 10 meters high, and fed through buried and well decoupled coax lines. They are not influenced neither by very close Pennants, nor by the elevated radials and only mildly by the low dipole. They see, of course, the TX vertical antenna, but its effect can be completely cancelled with a detuning stub.

At this point a question arises: is in the real world a detuning short stub feasible with a shunt-fed grounded tower? (by simply connecting a ¼ wave short stub at the gamma capacitor, by means of relay switching). Or must be applied the more complex technique suggested by Tom Rauch, W8JI, in one of his "great" Web pages? (See: www.w8ji.com/detuning_towers.htm).

October 2004 Luis, IV3PRK

P.S.: As a matter of fact, in Sept. 2007, I installed the detuning system by W8JI - See this page:
https://d.docs.live.net/0851f36be2efa81b/File%20per%20SuperSite/Detuning%20tower.pdf