Rx antennas at IV3PRK: the 4-Square Rx Vertical Array

Part 3: Installation, tuning and testing

by Pierluigi "Luis" Mansutti IV3PRK

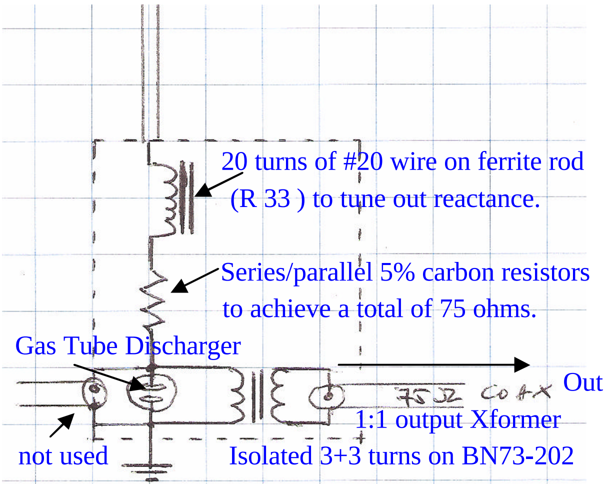
The ground system connections

After many e-mail exchanges and deep discussions with my helpful and expert friends Lee, K7TJR, and Jerry, K4SAV, I followed Lee's advice to isolate the feedlines from the single verticals with an isolated winding 1:1 output transformer. This would eliminate any ground loops for each of the separate antenna signals sent to the central control box.

That seemed to me a great idea because it solved also the problem to keep the antennas always with a DC ground connection, also when the array is not in use and during the storms.

Fortunately I had some binocular cores BN73-202 left and, as only 3 turns for each winding are needed, I could use a thick wire (#20) for a solid DC ground connection on the primary. On the secondary winding I used #26 gauge wire into a small Teflon tube, in order to avoid any scratching and to reduce interwinding capacitance.

I just put another F-connector on the PVC box and left the gas tube discharger where it was, across the previous grounded F-connector.



Wiring diagram of the antenna matching box

All provisions have been taken to avoid ground loops and unwanted signal or noise incursion between radials and feedlines, and to get also the best possible lightning protection.

As seen in the next ground system drawing, there are three separate grounds:

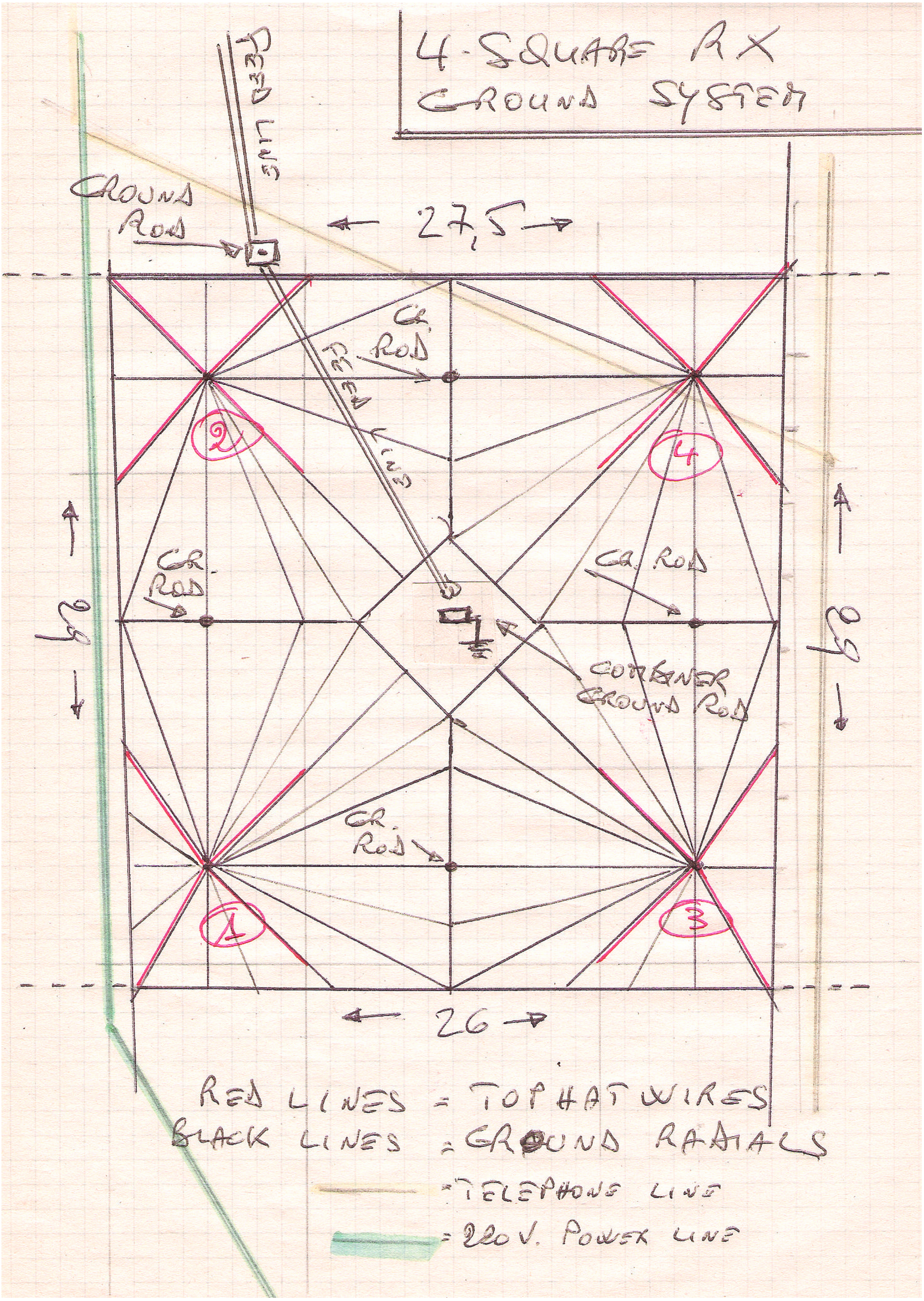
1) the verticals have their own ground system and are isolated from the coax lines and from the central box

2) the feedlines to the elements and the phasing lines are grounded only at the combiner central box through a separate ground rod

3) the RG213 feedline to the shack is isolated from the combiner and has another separate ground rod outside of the array.

So the antennas are isolated from the central box, and the central box is isolated from the feedline going to the shack. Jerry says that item 2 or 3 are unnecessary but, with my hostile environment and all the constrains of my lot, I didn't want to leave anything unattempted!

A matching box completed and tuned



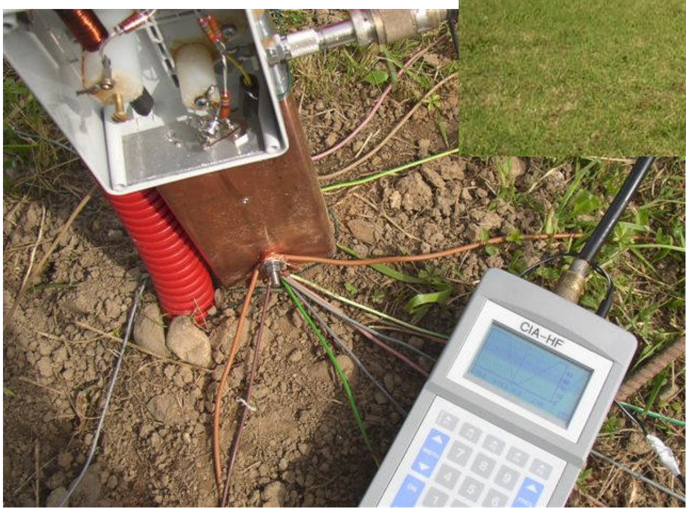
4-SQUARE RX
GROUND SYSTEM
FEED LINE
GROUND ROD
27,5
GR. ROD
FEED LINE
2
4
GR. ROD
GR. ROD
26
CORNER GROUND ROD
26
GR. ROD
1
3
26
RED LINES = TOPHAT WIRES
BLACK LINES = GROUND RADIALS
= TELEPHONE LINE
= 220 V. POWER LINE

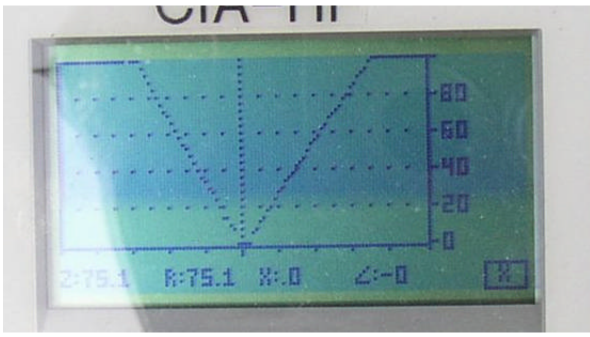
Installation and impedance matching

Complete view of the 4 square Rx array installed on the fenced 26 x 29 meters lot.

All the feedlines have been buried in plastic conduits, although the good quality of flooded coax cable.

Then the symmetric ground system was laid down and soldered at the junctions, with 15 radials for each antenna.





With the antenna analyzer AEA CIA-HF it was easy to null out reactance and achieve the required R 75 + jX 0 on three verticals, but … strange and difficult on antenna n. 4, which is too close to a single telephone cable crossing my lot to reach a neighbor depot.

The following were the values of the resistors required to achieve the 75 ohms on the different antennas. As the ground resistance is believed to be uniform, the differences should be due to the more or less vicinity of the utility lines.

Ant. 1 : 51 ohms
Ant. 2 : 47 ohms
Ant. 3 : 54 ohms
Ant. 4 : 32 ohms.

On antenna n. 4 it was also necessary to reduce one turn on the inductor.

Attention:** after removing the crossing telephone cable, all the antennas had to be matched again and the definitive correct values are those **on page 8.

Ant. N. 4 with the close crossing telephone cable

A further common mode choke on the feedline to the shack

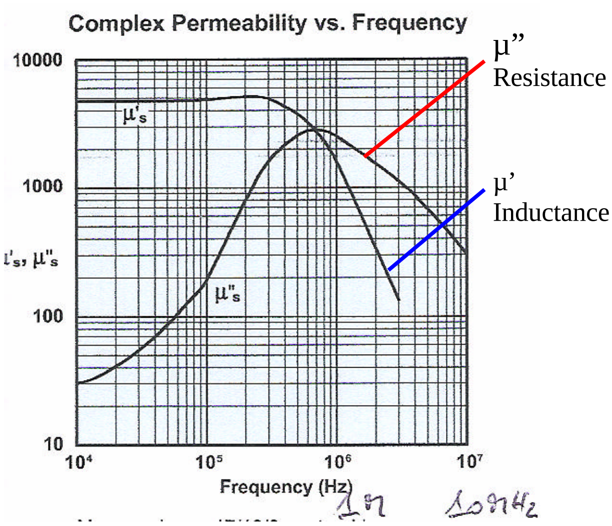
All the attentions in this project were taken against the common mode noise and I decided to insert an RF choke also on the RG213 feedline to the shack, although my friends said it unnecessary …but I'm living in very noisy environment and the care is never too much!

During the years I have been trying to learn all what I could on transformers, RF chokes and ferrite materials. A lot of info can be found in many posts on the Topband Reflector and in some specific documents like the K9YC RFI tutorial http://audiosystemsgroup.com/RFI-Ham.pdf , but the main source is the Fair-Rite catalogue.

Many years ago I bought from Amidon several FT 140A-J toroids, which I always used as RF chokes, but unfortunately the K9YC tutorial does not take into consideration this 75 material.

So I tried myself to verify the characteristics of these toroids. The AL number is very high, 6800, and "J" material is the same as 75, with an initial permeability μ' = 5.000. But this parameter effects the inductance of the winding and it is important only for transformers. In the case of RF suppression we need not reactance, but resistance, whose related parameter is μ".

At the frequency of 2 MHz μ" is around 1600 (while μ' goes down to 300), and thus it seems a very suitable material.



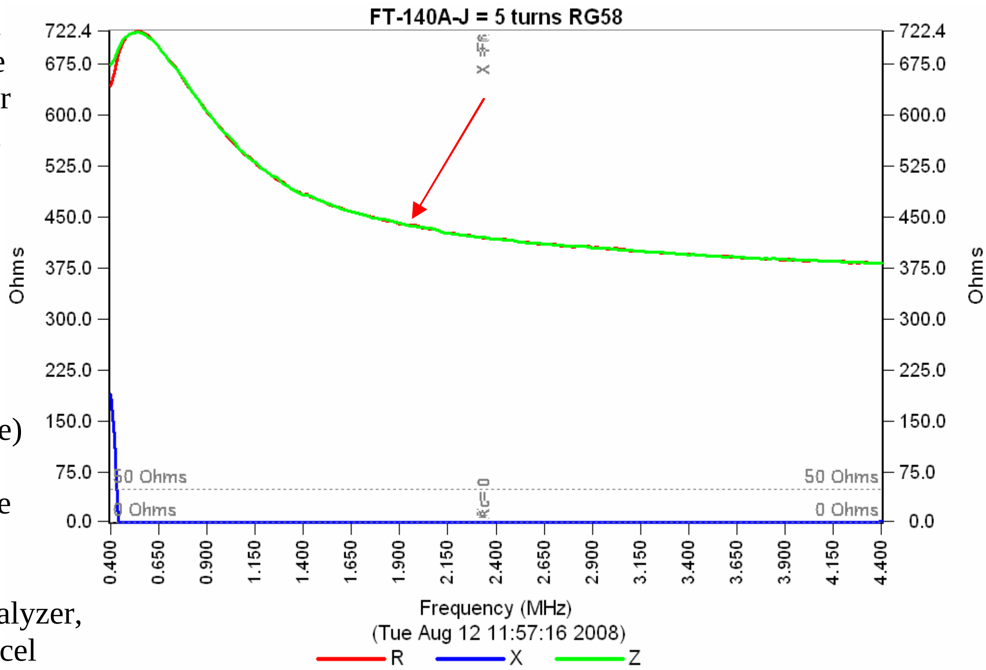
75 Material

75 Material Specifications:

Property	Unit	Symbol	Value
Initial Permeability @ B < 10 gauss		μ_i	5000
Flux Density @ Field Strength	gauss oersted	B H	4300 5
Residual Flux Density	gauss	B_r	1400
Coercive Force	oersted	H_c	0.16
Loss Factor @ Frequency	10^{-6} MHz	$\tan\delta/\mu_i$	15 0.1
Temperature Coefficient of Initial Permeability (20 -70°C)	%/°C		0.6
Curie Temperature	°C	T_c	>140
Resistivity	Ω cm	ρ	$3x10^2$

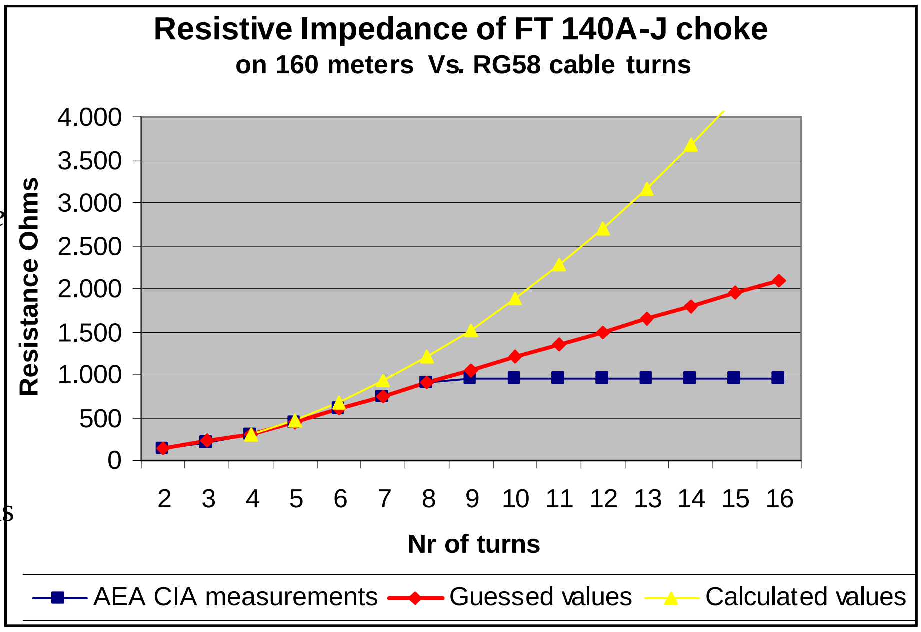
The impedance required for a choking effect on 160 meters is at least 1.500 ohms, and higher is better, but that’s above the range of my antenna analyzers, RF1 Analyst and the AEA CIA, so I had to develop a tricky graph with the computer to guess the results.

I wound some turns of thin RG58 coax on the toroid and got the data on the CIA analyzer (in series with a 50 ohm resistor) for each turn increment .



The readings are as expected, with the impedance determined by resistance only (red and green curves) while the reactance (blue curve) is zero.

The data increase with a linear trend from 2 to 8 turns, where they reach the limit of the analyzer, and I put them on an Excel sheet to build a graph.



The yellow line is calculated with the square increments of the turns, as sentenced by W8JI on May 22, 2001 “ …*impedance increases by the square of the turns in a multiturn choke and only at a direct proportional rate with length of the choke for beads.”*

But it seems getting exaggerated values and don’t match closely with the real measurements in the low turns region.

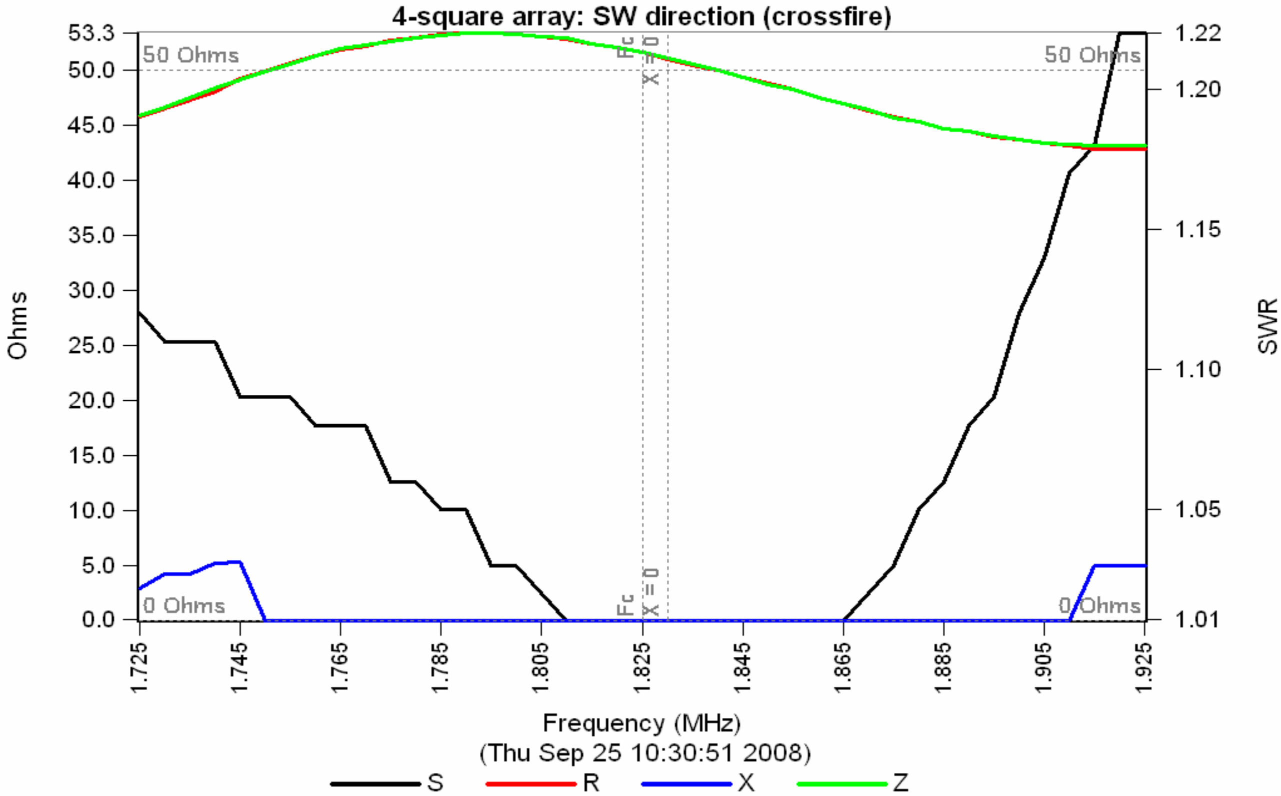
So I think that the red line, built with the same rate increase of the effective readings of the first 8 turns, should be better guessed… in any case above the required value.
With a 16 turns coax winding, which fits on a FT 140A-J toroid, over 2.000 ohms of resistive impedance are surely achieved and, in addition to the isolated binocular transformer, should be more than enough for a “quiet” feed system to the 4-square array.

I buried this RF choke in a drain well between two ground stakes to provide a low impedance path to the earth for both the noise on the coax shield and lightning protection.

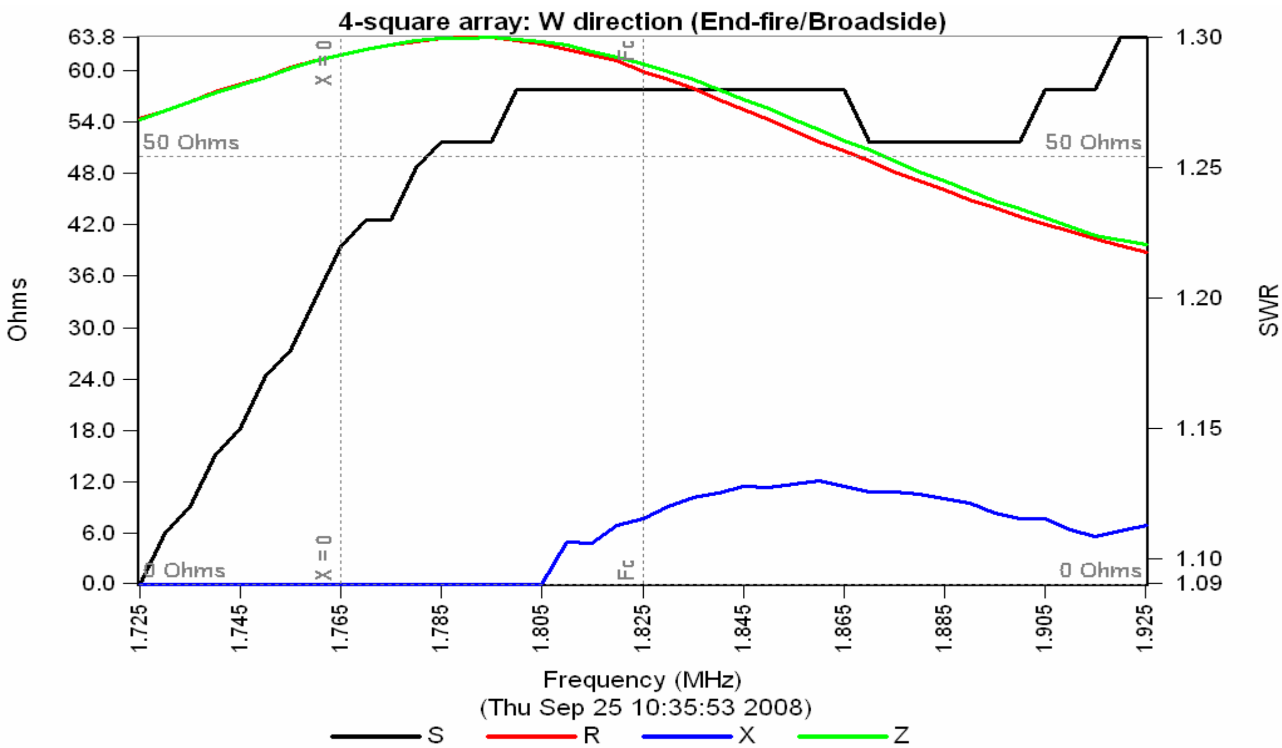
RF choke: 16 turns of RG58 on FT140-J

First tests of the array

With the AEA analyzer I performed a sweep reading in the shack for each switching position and everything works as expected. The diagonal or crossfire positions are perfect:



While the other end-fire/broadside positions are still acceptable, but with some slight differences from one to another:



On the air tests

Here came the disappointment and these are my notes for September 24 and 25:

The array works as it should, with a very good front to back ratio, but a prohibitive noise level.

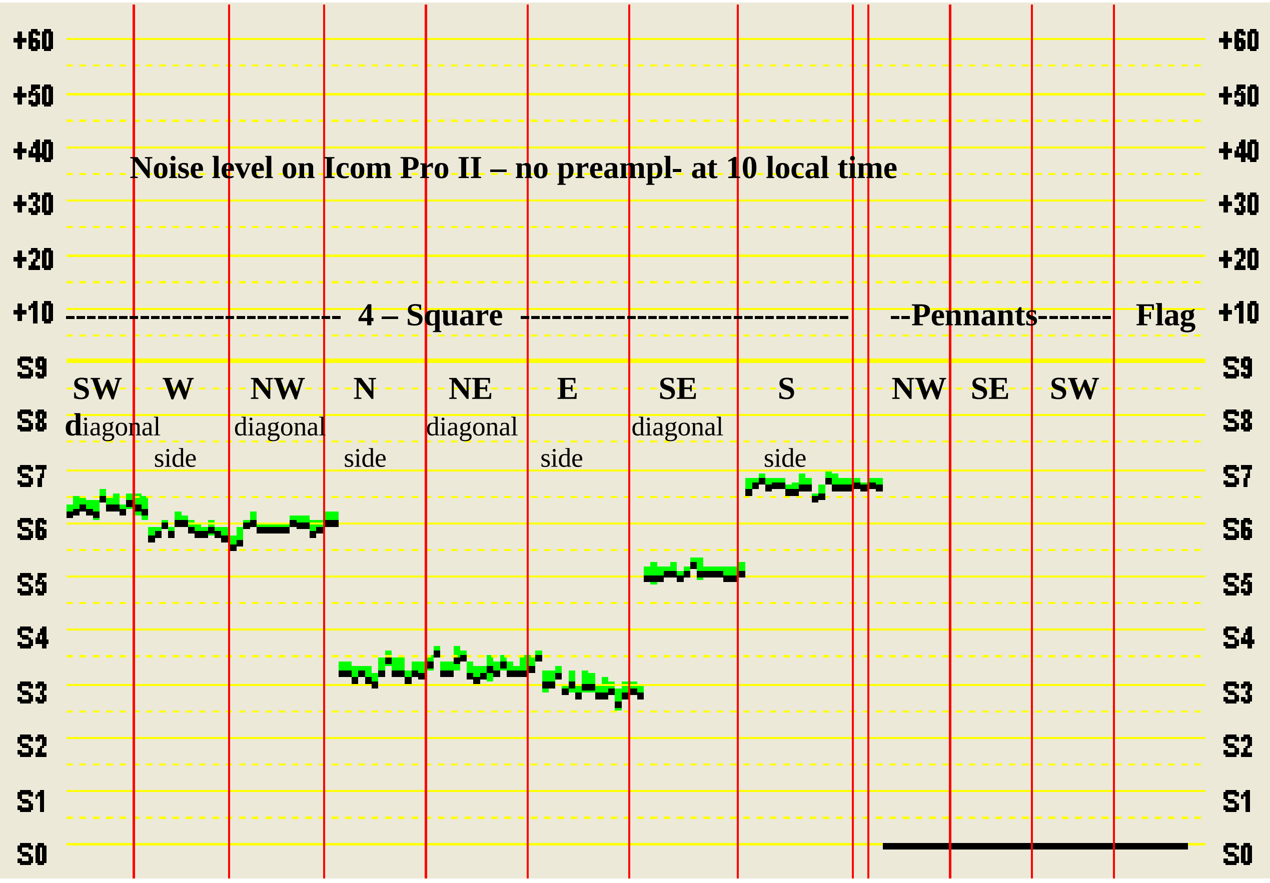
I can hear the European stations only on two or three contiguous positions; on the back they are all buried in the noise. In the crossfire (diagonal) positions the F/B is much better than in the end-fire/broadside (side) ones, where the signal is always stronger: everything as expected. Of course I could not measure anything because the s-meter does not go below S 9.

Last night conditions were good with Japan but I could hear them only on the old Flag and Pennants; these antennas have less directivity and F/B but are very quiet.

This morning I checked again between 04 and 05 local time; conditions were very good between W6/W7 and Scandinavia, but here the band was very quiet, almost dead.

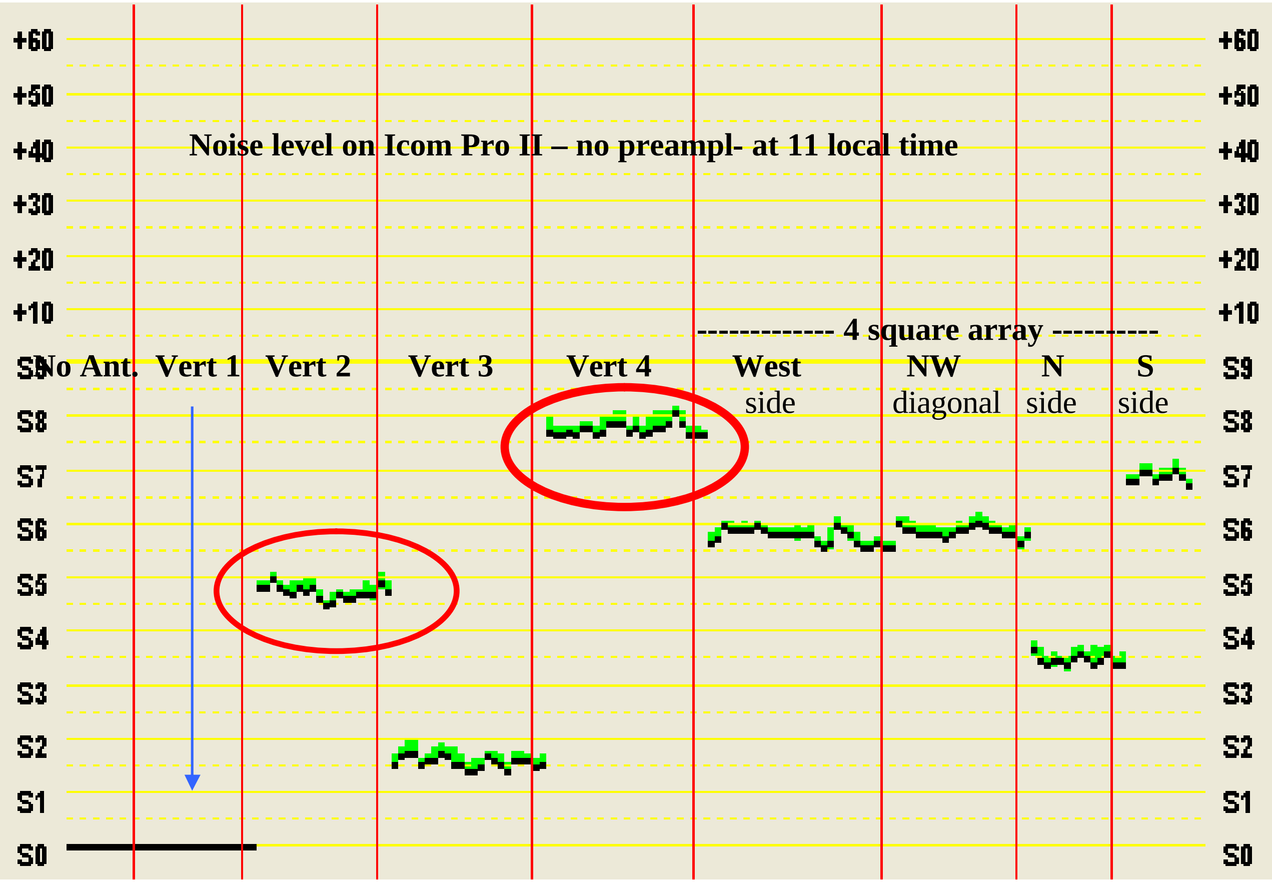
The noise level on the Orion S-meter was: S 1/2 on the north west pennant
S 3 on the rotatable flag
S 9 on the 4 square array !

I made some more tests during daylight to measure and print the S-meter readings of the noise level on the 8 positions of the 4-square array and on some other Rx antennas.



Then I connected each of the single 4-square elements directly to the feedline going to the shack and the results were amazing: <u>almost 40 dB of noise difference between the best (vert. # 1) and the worst (vert. # 4)</u> confirm that:

1. there is no problem with common noise on the feedline
2. the noise seems to be <u>originated only by the telephone line</u>, and not the power line.



So the problem had to be solved with the Telephone Company and ask them to find another route for that cable.

September 25, 2008

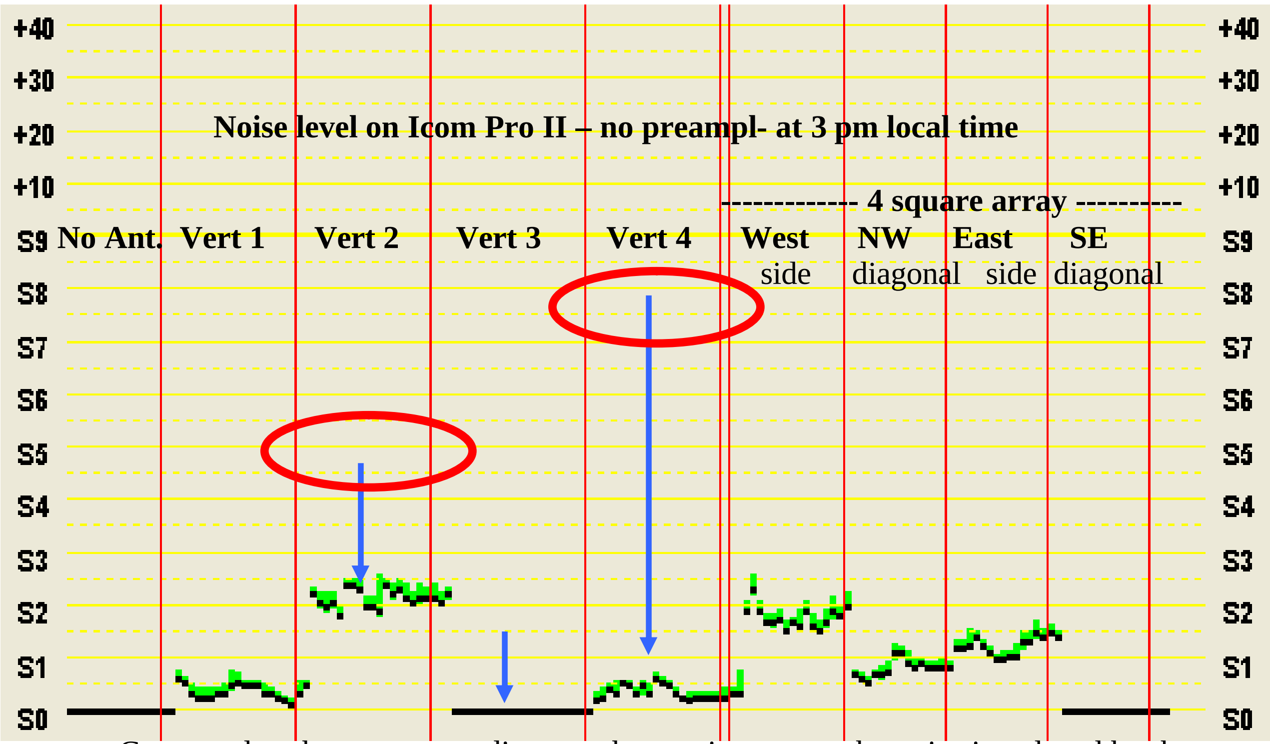
Removed the offending cable

At first it seemed not easy to get a prompt reply and a solution from the company, but my neighbours were collaborative and let me make some tests while disconnecting any modem or fax equipment from their line. Nothing changed… so I decided to climb myself the two telephone poles, unhook the offending cable and find for it another route about 30 meters far from the array.

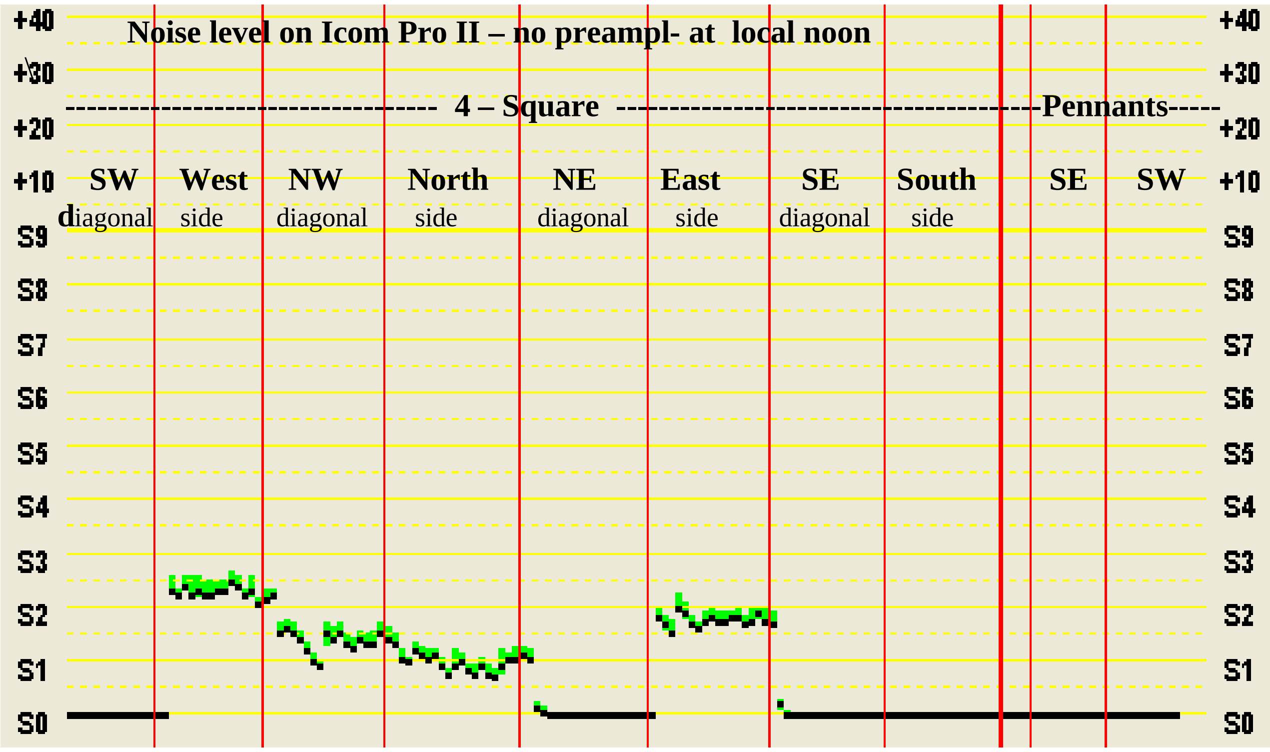
The noise immediately decreased, and then I had to match again the impedance of the single elements. The following are the loading resistance variations required to achieve R 75 + jX 0 at the base of each vertical:

1. no changes, still = <u>51 ohms</u>
2. from 47 added 3 ohms = <u>50 ohms</u>
3. from 54 reduced 1 ohm = <u>53 ohms</u>
4. from 32 added 20 ohms = <u>52 ohms</u>, plus from 19 to 20 turns on the inductor (as the others).

These are the s-meter noise readings taken directly on each antenna unhooked from the array, and then on the 4-square as a whole:



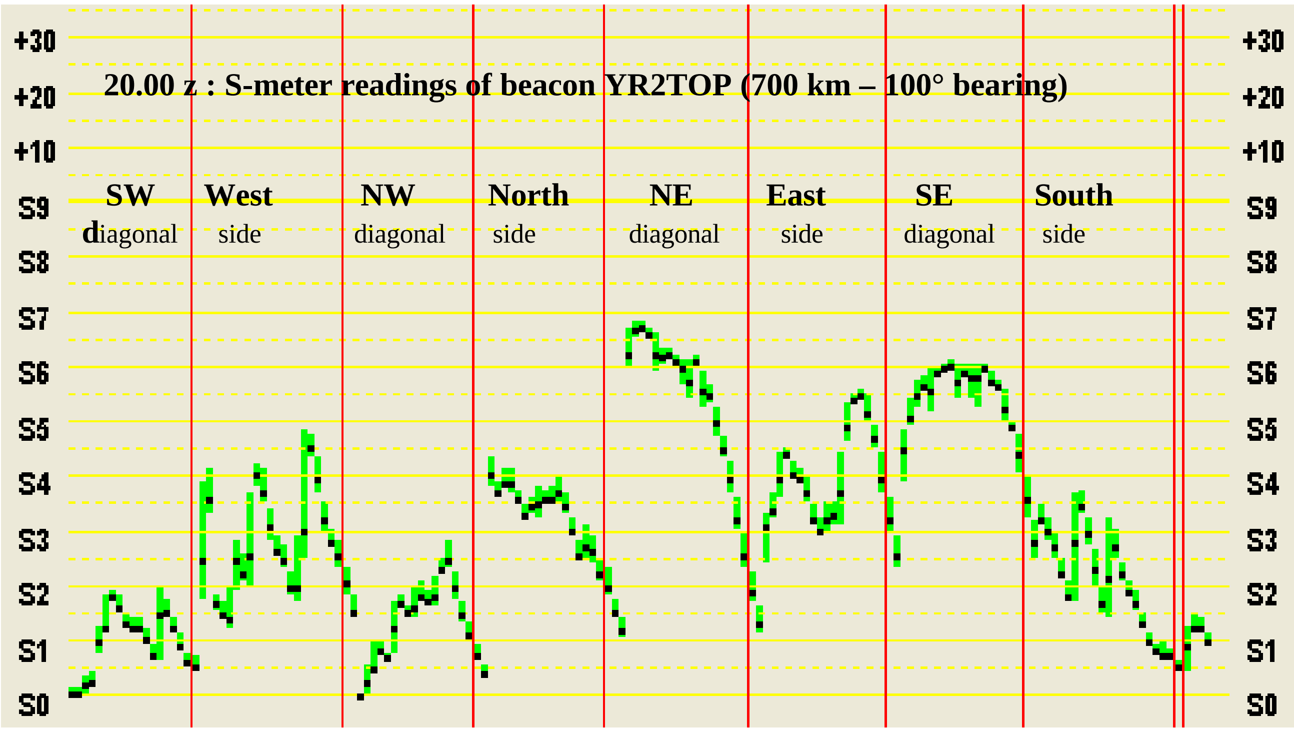
Compared to the s-meter readings on the previous page, the noise is reduced by three s-units on Vert.2 and by seven s-units on Vert.4 (the closest to the offending telephone wire). But it is not yet perfect due to some noise still captured by Vert.2 : that's my local environment problem !



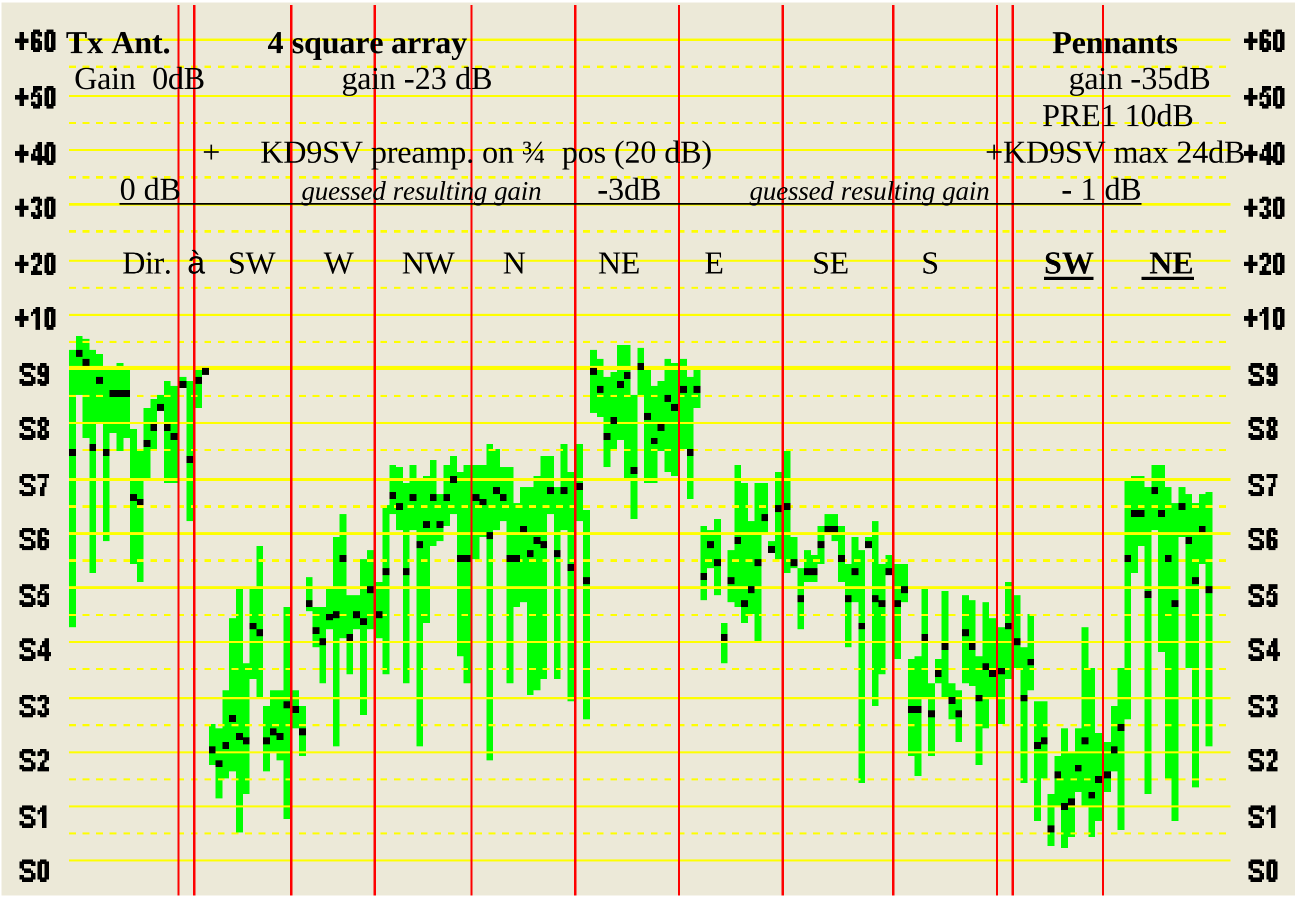
On all the side positions the noise is higher as the 8 dB attenuator has not yet been inserted.

There have been not many DX stations to test last night, but I could notice for sure in every case at least 20 dB of front to back in the expected direction and I tried to get uniform readings on the YR2TOP beacon (at the 100 W level).

Albeit the QSB we can see on the next printout that the array works as it should, better in the diagonal (crossfire) positions, and less pronounced in the side (end-fire / broadside) positions.



A much better shape is shown after the projected 8 dB attenuator was inserted on all the side positions (of -15 dB gain). It's impossible to get uniform s-meter readings on DX stations, so these are the results on the **OK0EV beacon on 1.854 KHz (in JN79 at 400 km. distance – NE direction**



The signal is peaking clearly only on one of the eight switching positions, and the 30 dB F/B seems to fulfil one of my project requirements: a back high angle null, in order to reduce the close European QRM.

October 2008 Luis IV3PRK