

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

Part 2: putting all stuff together and construction details

by Pierluigi "Luis" Mansutti IV3PRK

Calculating the cable lengths

The most difficult choice, and the only stuff I had to buy, was the coaxial cable. I was going to order the RG6 cable to K7TJR. Lee is a great friend, very helpful, and sells best quality and cheap stuff, see <http://www.hizantennas.com/index.htm>, but nowadays shipping expenses from U.S. to Italy are sometimes twice the merchandise value.

So I found locally the following Italian cable (for buried use) in stock at a convenient price (0.48 Euro/meter) and all the F connectors and installing tools.

Technical specification



Coax H- 325 AL PE



Description

75 Ohm coaxial cable suitable for broadband HFC/CATV or SMATV signal distribution . Gas injected foam dielectric. PE outer sheath.

PHYSICAL CHARACTERISTICS

Inner conductor :

Number of coax	1
Total number of conductors	1
Conductor diameter	1.00 ± 0.012 mm
Conductor material	CU – bare copper

Insulation

Insulation material	Gas injected foam Polyethylene
Insulation diameter	4,80 ± 0.05 mm

Outer shield

	<i>Layer 1</i>	<i>Layer 2</i>
Outer shield type	Tape	Braid
Outer shield material	Aluminum/Polyester/Aluminum	Tinned copper
Coverage	100%	48%

Outer sheath

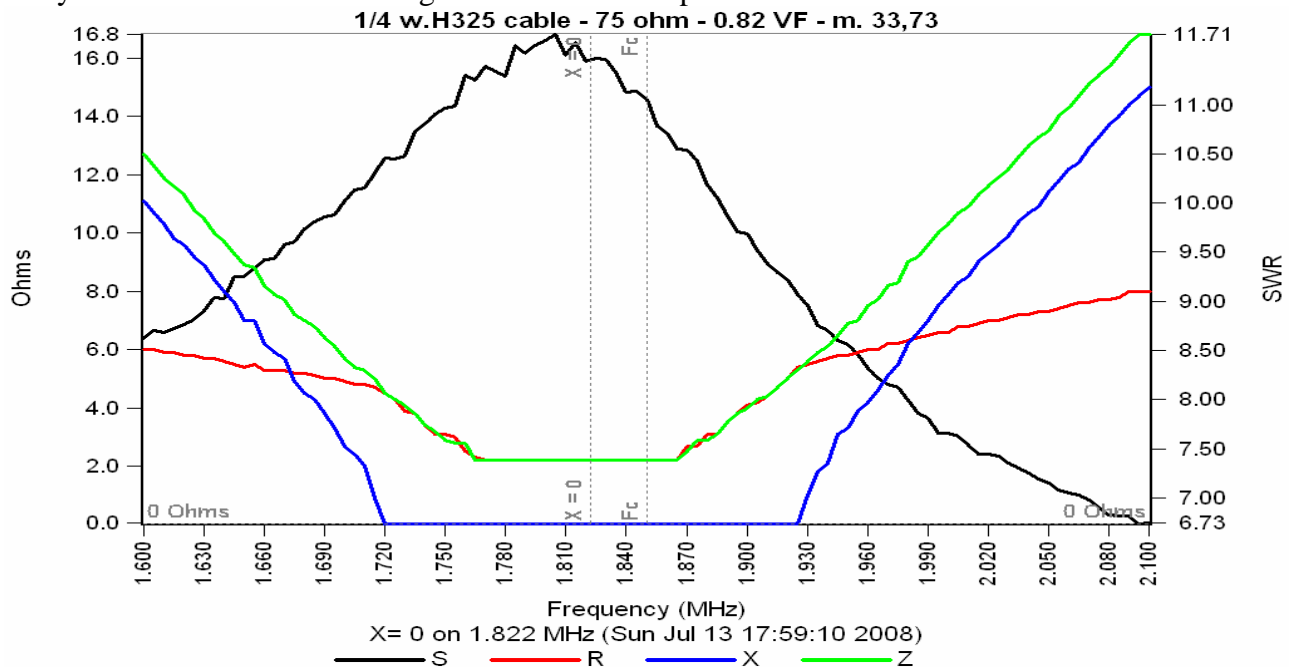
Outer sheath material	PE (Polyethylene)
Outer sheath diameter	6.80 ± 0.10 mm

ELECTRICAL CHARACTERISTICS

Nominal characteristic Impedance	75 ± 3 Ohms
Nom. Capacitance Conductor to Shield	55 ± 2 pF/m
Nominal Velocity of Propagation	81%
Nom. Inner Conductor DC Resistance	22 Ohm/Km @ 20° C
Nom. Outer Conductor DC Resistance	20 Ohm/Km @ 20° C
Voltage Test of Dielectric	2.5 kVdc
Voltage Test of Sheath	3.0 kVdc

→ 82%

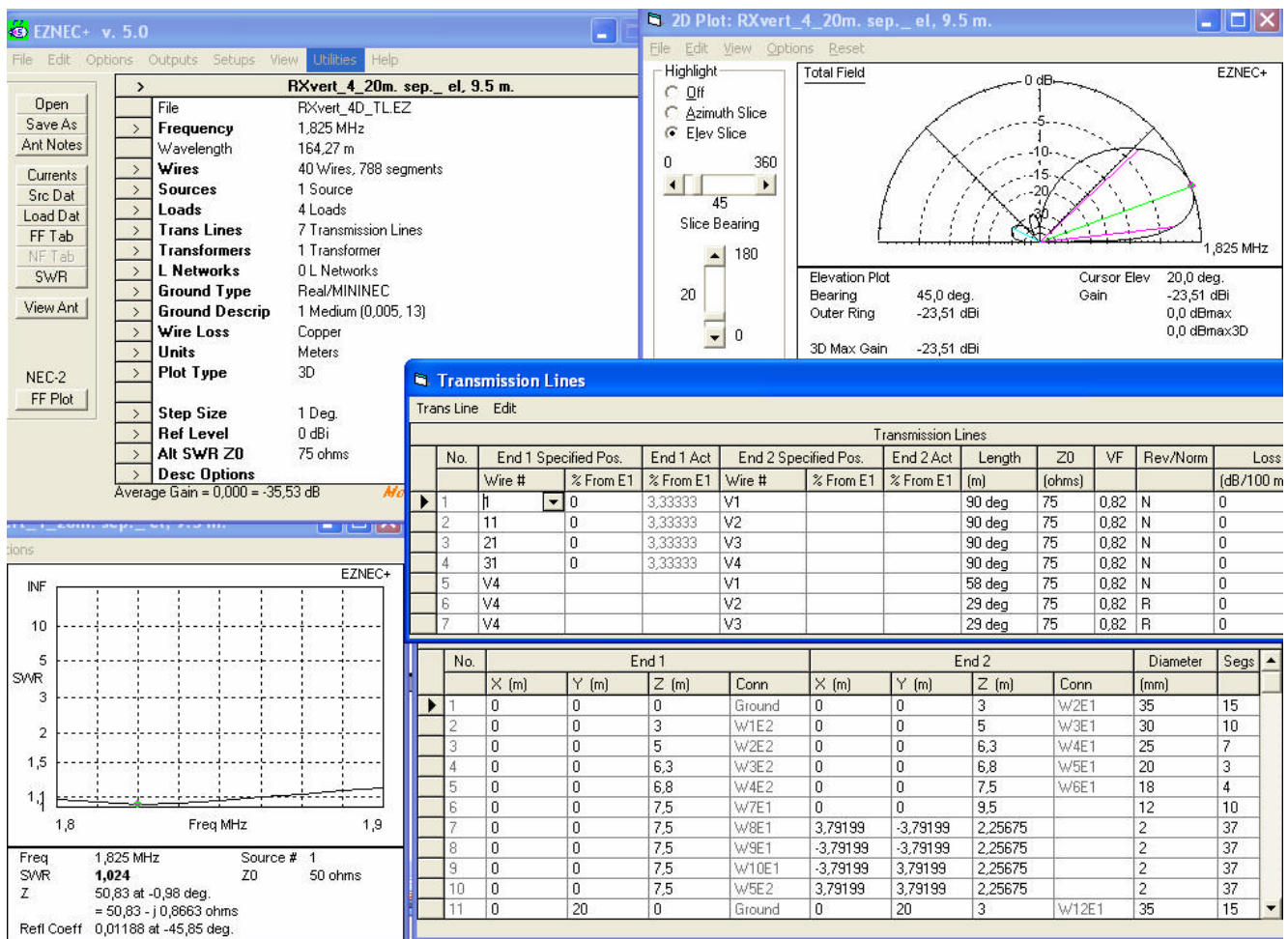
As recommended, at first I measured the velocity factor on a quarter wave line with the AEA CIA analyzer and I found it something different from the published data.



Thus on my frequency design of 1.825 MHz a 90 degrees line would be 33,70 meters instead of the previously calculated 33,27 m. for a VF of 81%.

Then I put together the aluminium tubes and built the elements. After on site measurements, I realized that the maximum allowable separation between them should be 20 meters.

So with all the real wire dimensions I went back to Eznec to get the final model:



FINAL real model

Freq. 1.825

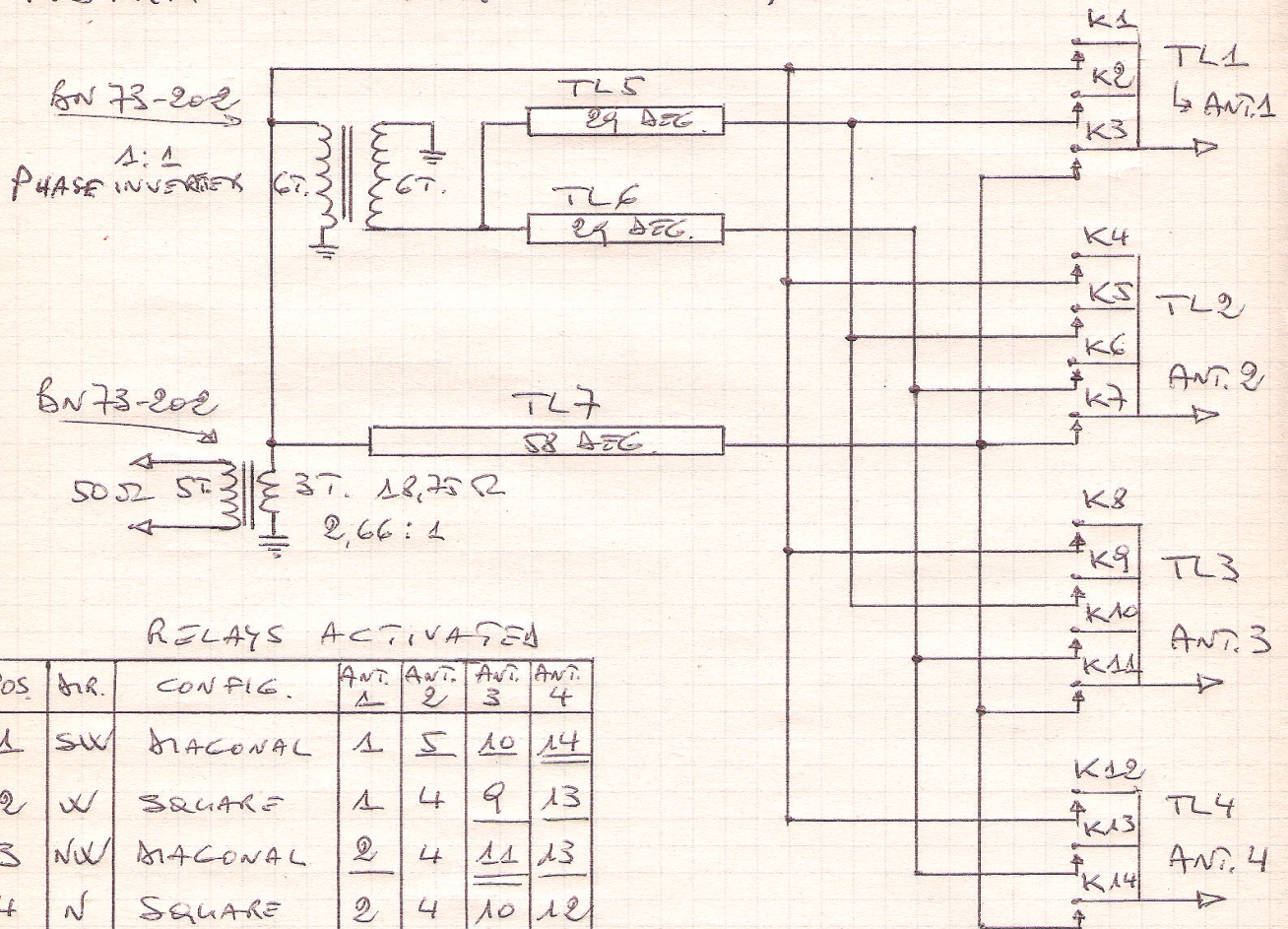
Rx Four Square Array: DIAGONAL beaming

EZNEC Model	Delay lines degrees		Delay lines meters		Gain	Take off angle	- 3dB BWdh	Front to Back	Average Gain	RDF	Secondary Back Lobe	Null Angle
Rxvert_4D_TL	Elem. 1	El. 2 - 3	Elem. 1	El. 2 - 3								
Top loaded 9,5 m. high												
20 m. separation												
Loads: R 74 + XL 295												
	58	29	21,70	10,85	-23,51	20	74	29	-35,53	12,02	26	50
Coax cable 75 ohm	- less inside cables		1,00	1,00	Quarter wave cables =		33,70					
VF = 82%	actual cables length		20,70	9,85	- less inside part		0,50	actual length =		33,20		
Crossfire feeding												

Rx Four Square Array: SIDE beaming

EZNEC Model	Delay lines degrees		Delay lines meters		Gain	Take off angle	- 3dB BWdh	Front to Back	Average Gain	RDF	Secondary Back Lobe	Null Angle
Rxvert_4E_TL	Elem. 1-3	El. 2 - 4	Elem. 1	El. 2 - 4								
Top loaded 9,5 m. high												
20 m. separation												
Loads: R 74 + XL 295												
	0	29	0,00	10,85	-15,48	22	115	13	-25,37	9,89	16	50
Coax cable 75 ohm	- less inside cables		1,00	1,00	Quarter wave cables =		33,70					
VF = 82%	actual cables length		-1,00	9,85	- less inside part		0,50		actual length =		33,20	
Endfire/Broadside Feeding												

1V3 RAK: RCV. 4 SQUARE ARRAY

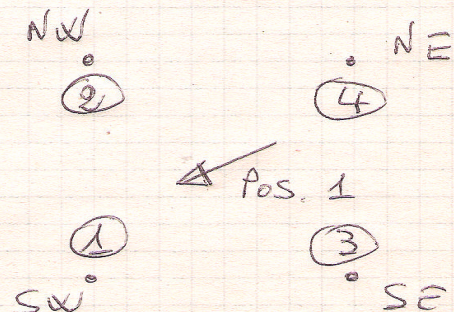


RELAYS ACTIVATED

Pos	dir.	CONFIG.	Ant. 1	Ant. 2	Ant. 3	Ant. 4
1	SW	DIAGONAL	1	5	10	14
2	W	SQUARE	1	4	9	13
3	NW	DIAGONAL	2	4	11	13
4	N	SQUARE	2	4	10	12
5	NE	DIAGONAL	3	5	10	12
6	E	SQUARE	2	6	8	12
7	SE	DIAGONAL	2	7	8	13
8	S	SQUARE	1	5	8	13

— : 29° DELAY

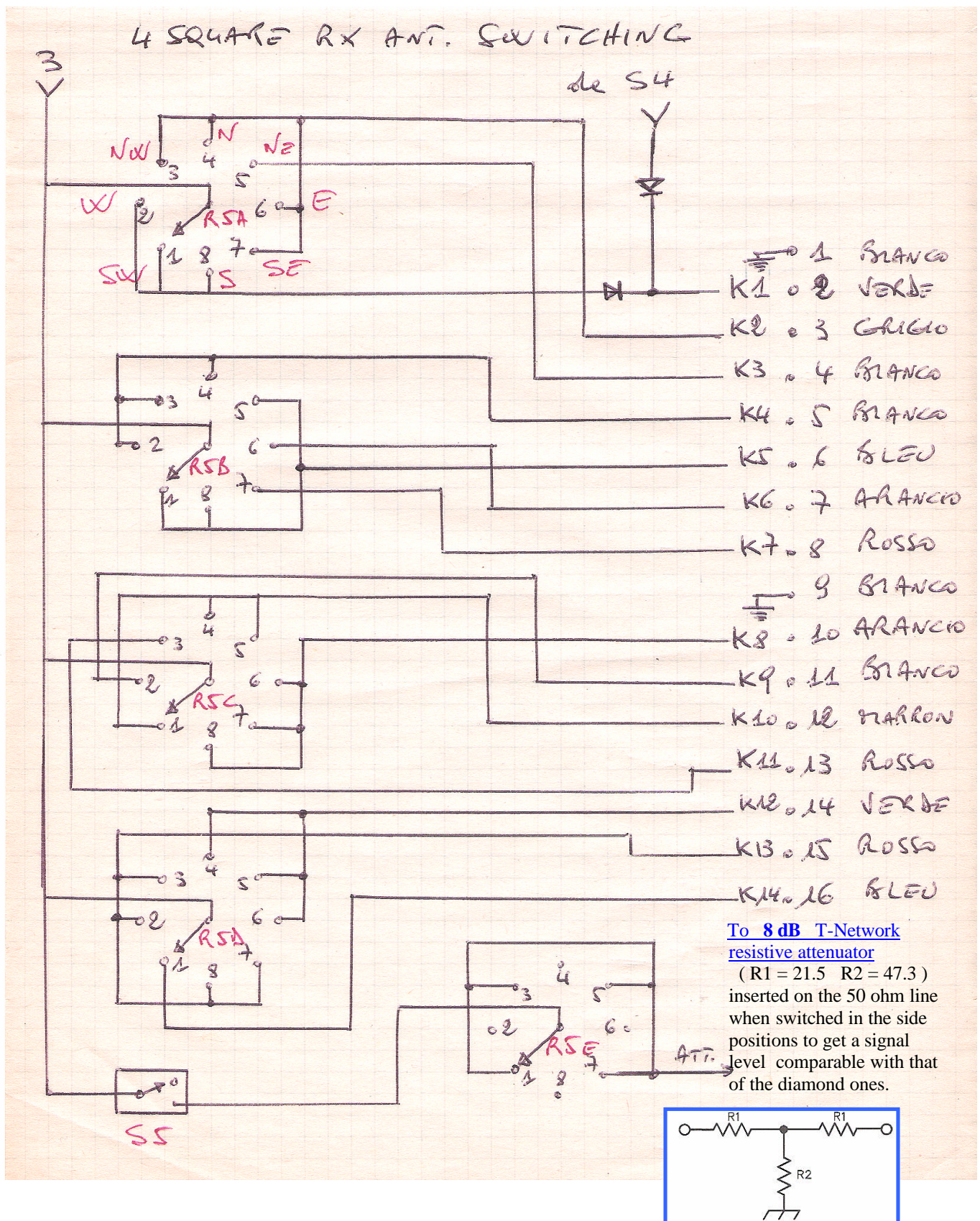
= : 58° DELAY



The switching box

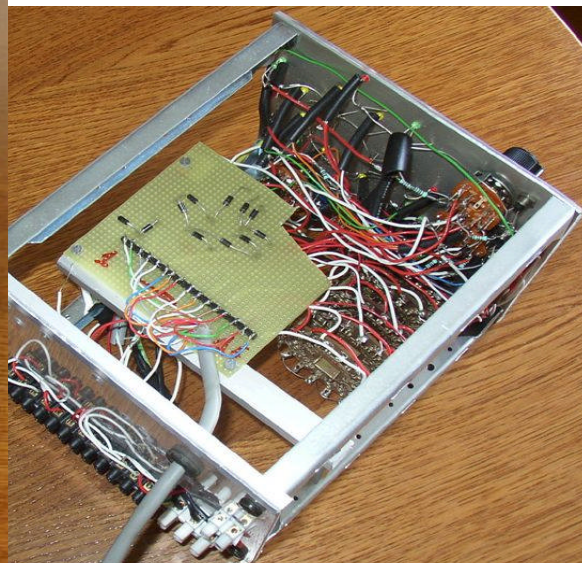
For the control line I got already a long 16 pole telephone cable which is going to be buried in a plastic conduit with the coax feedline. In the junk box I found an old suitable rotary switch, but even too big (8 positions, 10 poles) and I had to rebuild my Rx antennas switching box.

This is the sketch concerning only the 4 square array and the 16 wires control line codes.





The Rx antennas switcher box. The greater knob controls the 4 square array



Reversed inside view. On the right is the big 8 positions 10 poles rotary switch.

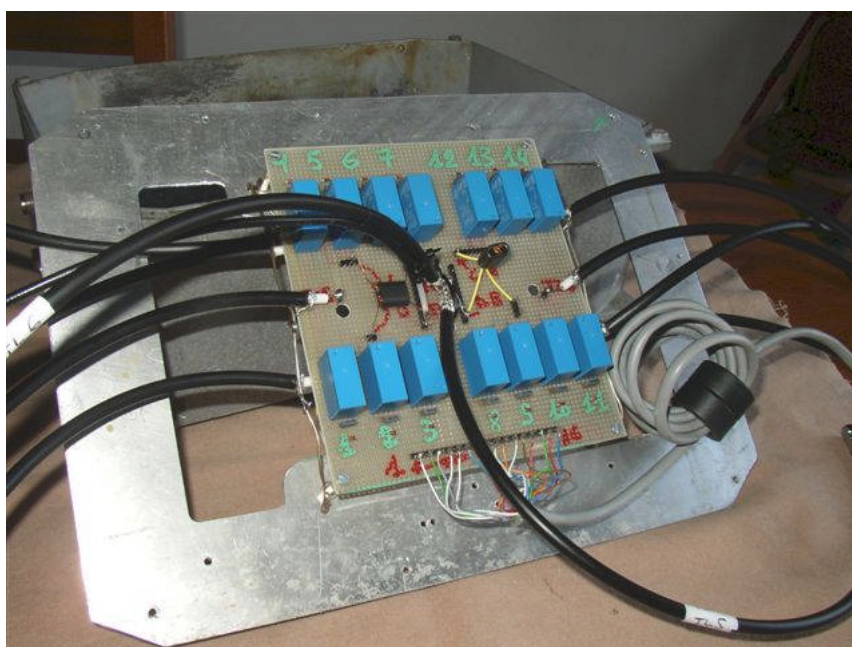
The combiner central box

Most of the stuff used in this antenna project was recycled from old dismantled works, so for the central box I got an aluminium sealed box of 30 x 40 x 15 cm. It seemed too large to keep the wires short from the relays board to the coax connectors., but there is enough space to fit some pieces of the rigid feedline. Instead of the simple chassis panel F connectors, I used all double female connectors and 50 cm. coax lengths to reach them. (F crimping connectors are cheap and installing them is very easy with the right tools!).

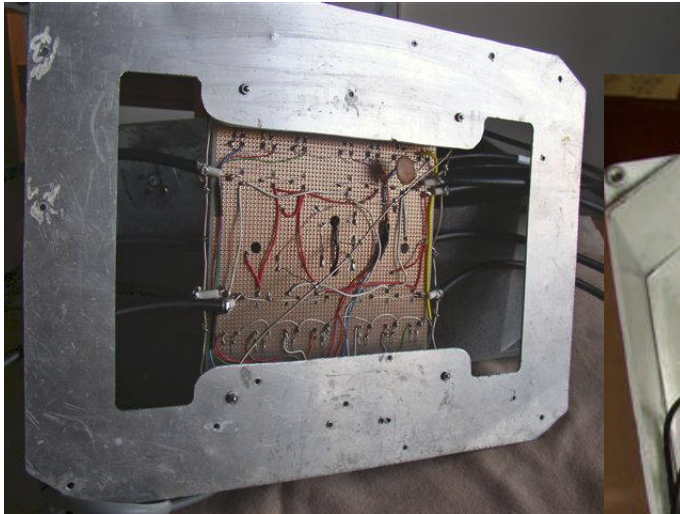
I bought the Tyco/OEG printed circuit board relays (OMI-SH series SPDT 16A 12V) from Mouser (at a reasonable price and their usual fast service), and put them on a perforated board on top of an aluminium plate.

I took all attentions for grounding and common mode isolation (K4SAV advice, tnx Jerry):

1. a separate windings output transformer with no ground connection with the feedline shield;
2. 10KpF capacitors in parallel with a reverse diode across each relay;
3. the negative side of the relay coil is grounded through a 10KpF ceramic disk cap (to isolate the DC ground for the relays and remove any signal that gets through the choke)
4. further common mode decoupling on the control line by winding it through two high impedance FT140A-J toroids.

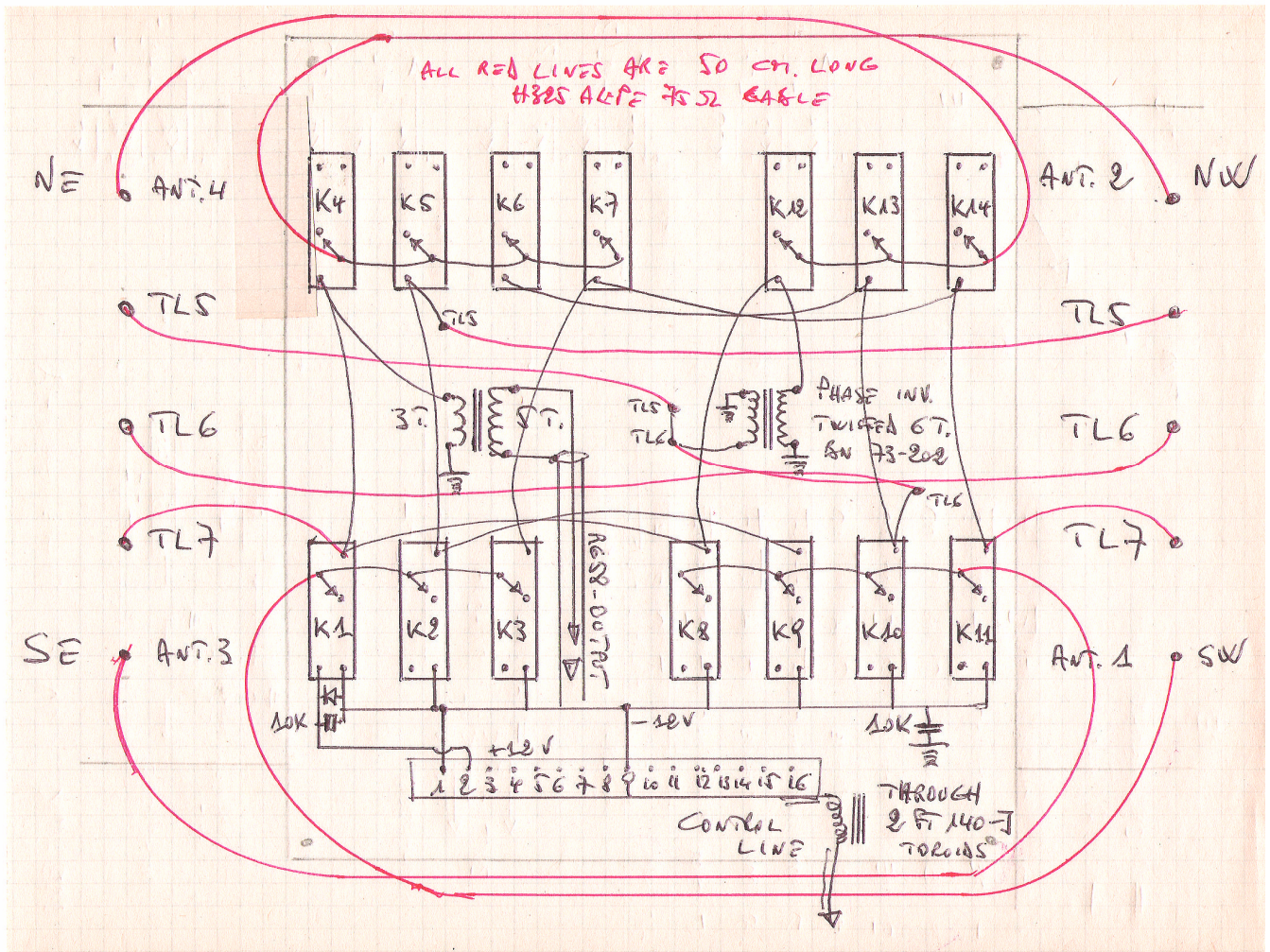


*Relays PC board with the binocular transformers.
On right down the choke on control line with 2 FT140-J cores*



On top: back view of the relays PC board

On side: the combiner box completed and ready for testing



Wiring layout of the combiner box. Red lines are all 50 cm. coax lines (subtracted from the calculated lengths). Each relay has same wiring of K1, but not shown to avoid cluttering.

On bench test

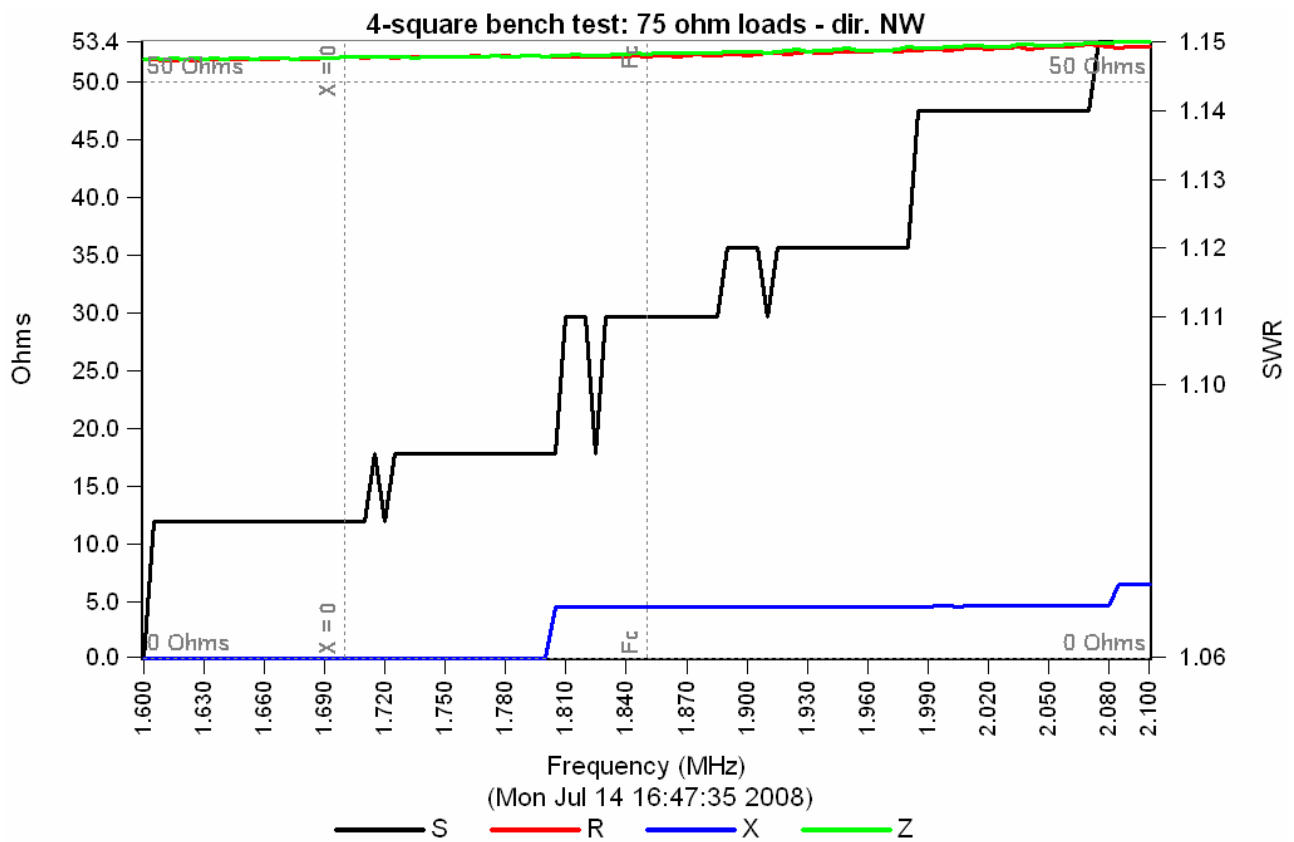
At this point it's a must to test the correct behaviour of the switching box, the relays sequence and the expected impedance transformations.

I prepared and connected all the delay lines and the quarter wave lines and I closed them with a 75 ohm load resistor. I brought the combiner in the shack and connected to the switching box and my AEA analyzer to check for the required 50 ohms output on every position.

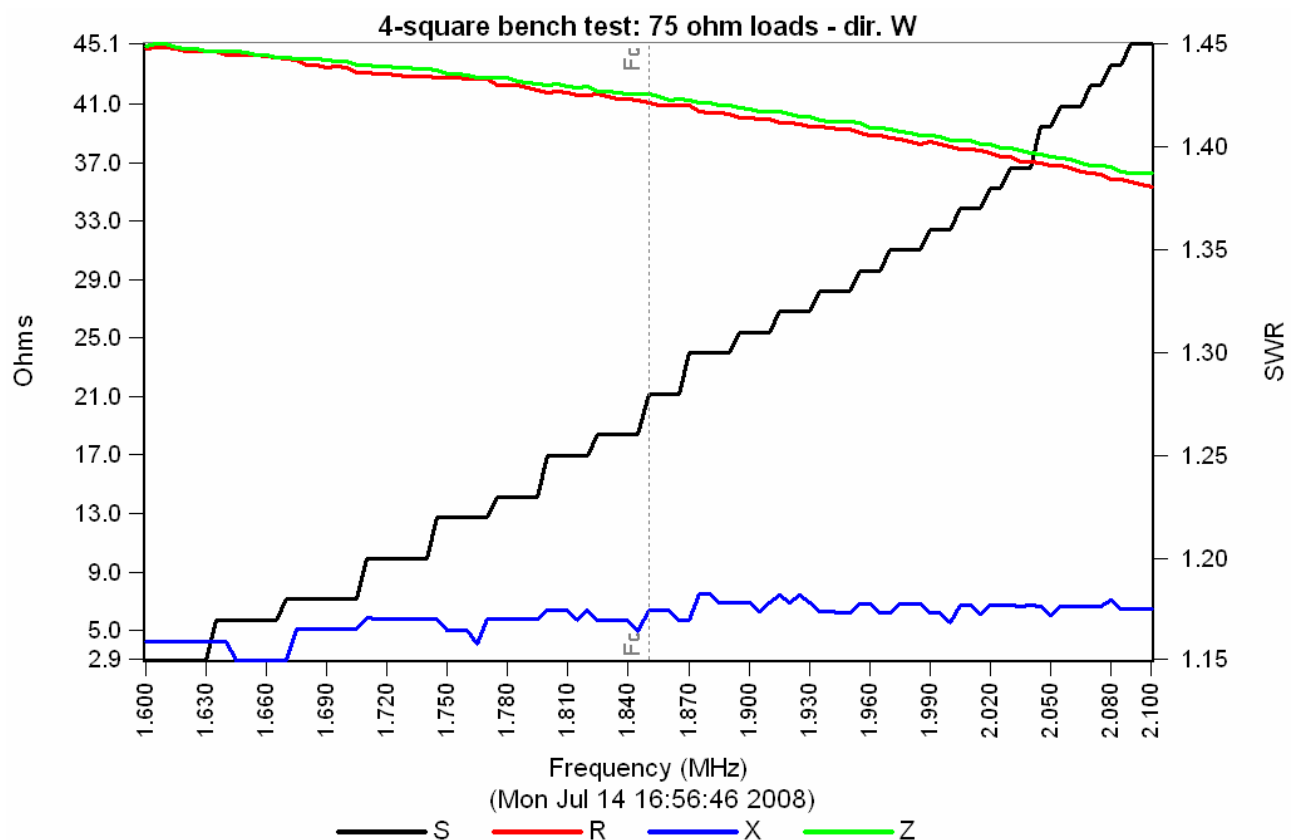


4 Square array Switcher and Combiner boxes with phasing lines test set-up.

After a couple of corrections the results were as expected. Almost perfect on all the diamond, or crossfire, positions, with an output impedance around 52 ohms.



Quite satisfactory also on all the side, (or broadside end-fire configuration), positions, with an output impedance around 42 ohms.



The antenna elements matching/loading boxes

In the typical electrical plastic box (80 x 120 x 50 mm) I glued some short pieces of nylon rods with soldering posts for easy on site substitution of the required series/parallel load resistors.

On a larger (20 mm.) rod I drilled a 9.5 mm. hole in order to fit an R33-037 ferrite rod. I wound 20 turns on it and, as calculated, I got an inductance of 25 μ H, i.e. about 290 ohms of reactance on 1,825 MHz. By sliding a little bit the ferrite rod through the hole and the winding I can get a wide range and a satisfactory precision. As a starting point I measured exactly 295 ohms of reactance on each of them and blocked on that position the rod with a compression screw.

The F chassis connectors are mounted on an aluminium plate which is connected with a short wire to the ground.



The verticals matching boxes with the homemade variable inductors and the loading resistors posts.

I have not yet decided to add here any kind of lightning protection like a spark plug or a small gas discharger.

From my previous 4 square receiving array I learnt how important is a good ground system, with the same stable values on all the vertical elements, so I dedicated my best care on it.

As a starting point, I completely wrapped the buried section (1 meter) of the wooden antenna supports (45 x 90 mm.) with a soft copper sheet. I have a good agricultural soil and I hope to be able to drive it that deep; the copper wrapping will protect the wood from moisture and offer a wide conducting surface. From there I will directly add as many radials as necessary !

At this point Jerry, K4SAV, came on with a further advice on common mode and lightning protection. He suggested to add :

5. an RF choke on the feedline output , and
6. to connect the coax shield, together with the -12VDC of the control line, to a new separate ground rod.

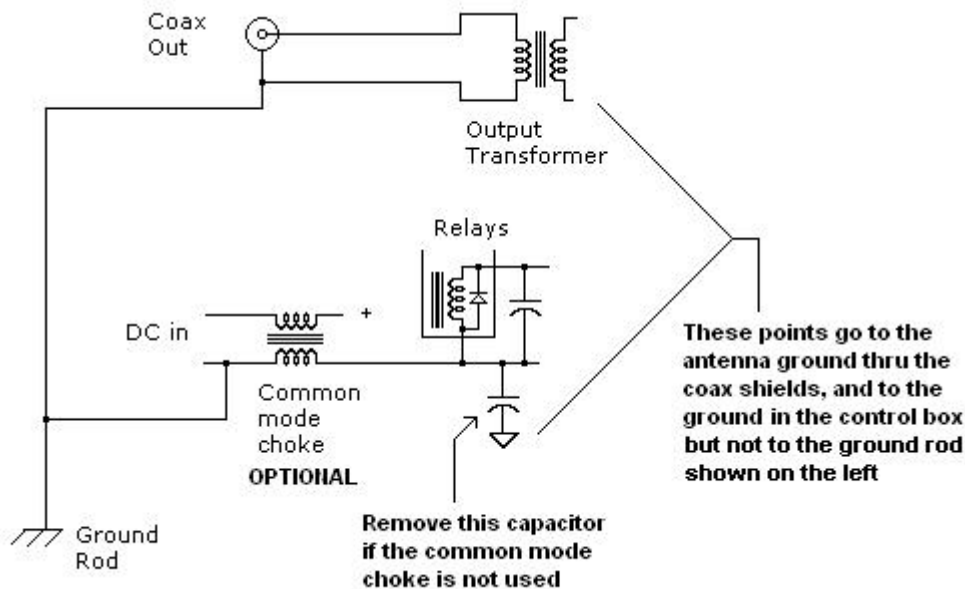


The antenna's supporting posts.

But after discussing that problem also with Lee, K7TJR, Jerry came to the conclusion that in my design, with an isolated transformer which assures good common mode rejection, there was no need for a further RF choke on the coax feedline.

Anyway we all agreed that a new separate ground rod, connecting the coax shield going to the shack and the -12VDC of the control line, was mandatory for lightning protection.

This is the sketch Jerry sent me to better explain the wiring. (Of course the SO239 socket for coax out is isolated from the aluminium box).



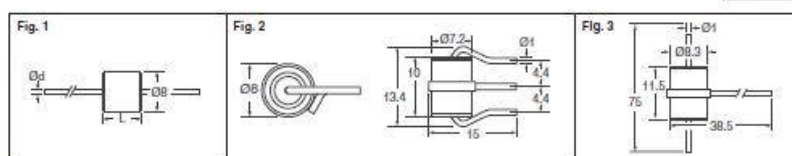
For further lightning protection I put a gas discharge tube across the F connectors at the base of each vertical. Of course they can't do anything in case of direct lightning, but they could prevent some damages from induced currents by close strikes. Anyway I'm not sure on their effectiveness, but I found them in my junk box and they are one of the following types (6 x 8 mm. in Fig. 1).

Surge Arresters

Gas-filled surge arresters offer optimum protection from atmospheric fields and discharges, inductive coupling from power supply lines, direct contact between communication and power lines, and electrostatic discharges. Epcon surge arresters limit overvoltages quickly and safely to uncritical levels and reliably discharge the resulting dangerous currents.

Specifications:

• Insulation Resistance at 100V: 10GΩ; Part No. A61-C90X, EC75X, EC90X, and T63-A90X Resistance at 50V: 10GΩ • Operation and Storage Temperature: -40°C - 90°C • Climatic Category (IEC 60068-1) 40/90/21



DC Spark-over Voltage (V)	Tolerance (%)	Nominal Impulse Discharge Current (Wave 8/20 μs)	Nominal Alternating Discharge Current	Cap. @ (1 MHz)	Dim. L (mm)	Dim. od (mm)	Digi-Key Part No.	1	10	Pricing 100	500	Epcon Part No.
Fig. 1												
75	±20	5kA	5A	1pF	6.05	0.8	495-1475-ND	1.41	11.75	94.00	411.25	EC75X
90	±20	5kA	5A	1pF	5.0	0.8	495-2631-ND	2.01	16.75	134.00	586.25	M51-C90X
90	±20	5kA	5A	1pF	6.05	0.8	495-1476-ND	1.41	11.75	94.00	411.25	EC90X
90	±20	20kA	20A	1.5pF	6.05	1	495-1472-ND	1.92	16.00	126.00	560.00	A81-C90X
290	±15	5kA	5A	1pF	6.05	0.8	495-1473-ND	1.41	11.75	94.00	411.25	EC290X
290	±20	5kA	5A	1pF	5.0	0.8	495-2632-ND	1.92	16.00	126.00	560.00	M51-A230X
290	±20	10kA	10A	1.5pF	6.05	1	495-1676-ND	1.68	14.00	112.00	490.00	N81-A230X
290	±20	20kA	20A	1.5pF	6.05	1	495-1471-ND	1.92	16.00	126.00	560.00	A81-A230X
270	-10/+25	5kA	5A	1.5pF	7.9	1	495-1477-ND	3.51	29.25	234.00	1023.75	L71-A270X
350	±15	5kA	5A	1pF	6.05	0.8	495-1474-ND	1.41	11.75	94.00	411.25	EC350X
350	±20	5kA	5A	1pF	6.05	0.8	495-2633-ND	1.92	16.00	126.00	560.00	M51-A350X
350	±20	10kA	10A	1.5pF	6.05	1	495-1679-ND	1.68	14.00	112.00	490.00	N81-A350X
470	-10/+25	5kA	5A	1.5pF	7.9	1	495-1478-ND	3.51	29.25	234.00	1023.75	L71-A470X
600	-10/+25	5kA	5A	1.5pF	7.9	1	495-1479-ND	3.51	29.25	234.00	1023.75	L71-A600X
1000	±15	10kA	10A	1pF	7.9	1	495-1489-ND	1.69	15.75	126.00	551.25	A71-H10X
2500	±20	2.5kA	2.5A	1pF	7.9	1	495-1470-ND	1.69	15.75	126.00	551.25	A71-H25X
Fig. 2												
90	±20	10kA	10A	1.5pF	—	—	495-1482-ND	2.46	20.50	164.00	717.50	T69-A90X
290	±20	10kA	10A	1.5pF	—	—	495-2634-ND	2.46	20.50	164.00	717.50	T69-A230X
290	±20	20kA	10A	1.5pF	—	—	495-1480-ND	3.06	25.50	204.00	892.50	T29-A230X
350	±20	10kA	10A	1.5pF	—	—	495-2635-ND	2.46	20.50	164.00	717.50	T69-A350X
350	-14/+59	20kA	10A	1.5pF	—	—	495-2636-ND	3.03	25.25	202.00	863.75	T29-C350XS
Fig. 3												
350	±25	20kA	20A	1.5pF	—	—	495-1481-ND	4.32	36.00	296.00	1260.00	T61-C350X

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