TK5EP's

4 square vertical system

This page is a short description of the four phased verticals system i've build and used. It is primarily intendend to be used on the lower bands 160m, 80m, 40m. All the principles stated here are of course valid for any other bands, but you can achieve the same game with yagi antennas easily. It is mainly built around the Collins hybrid phasing system wound on toroids.

Other feeding methods are possible and certainly better, but this one is rather simple to build and use on the battlefield. (contests, fieldays, expeditions)

Many stations use this system all around the world and it has proven his effectiveness.

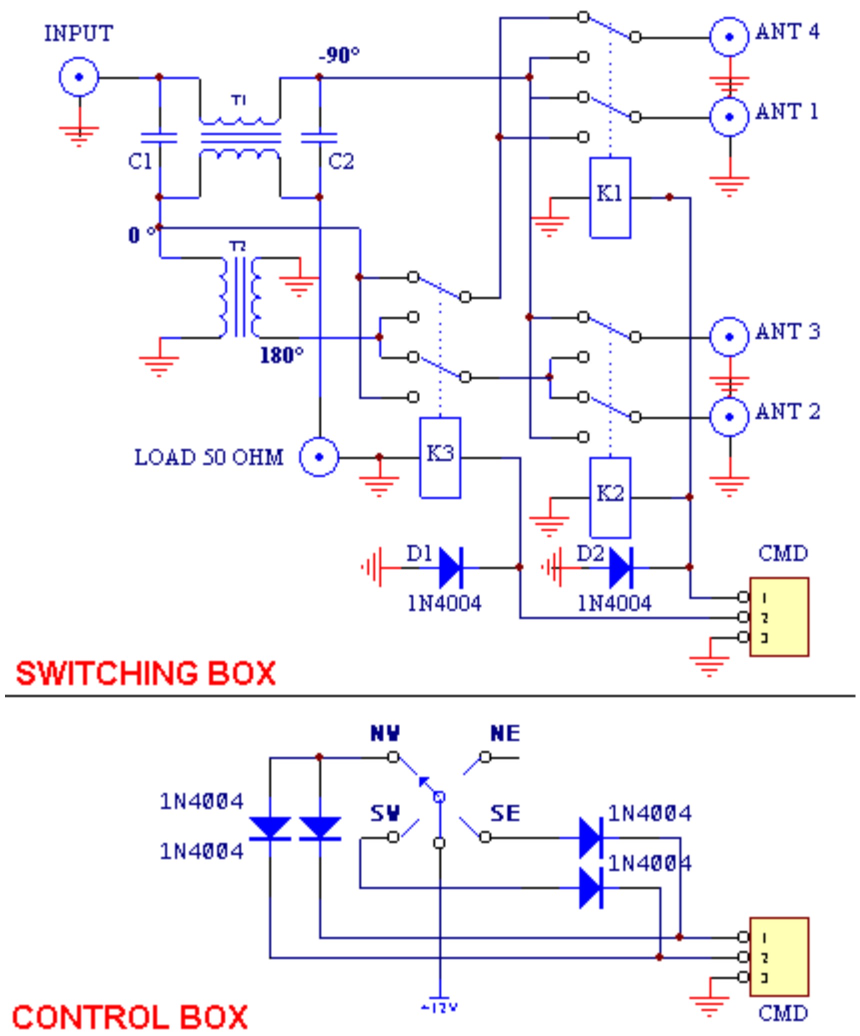
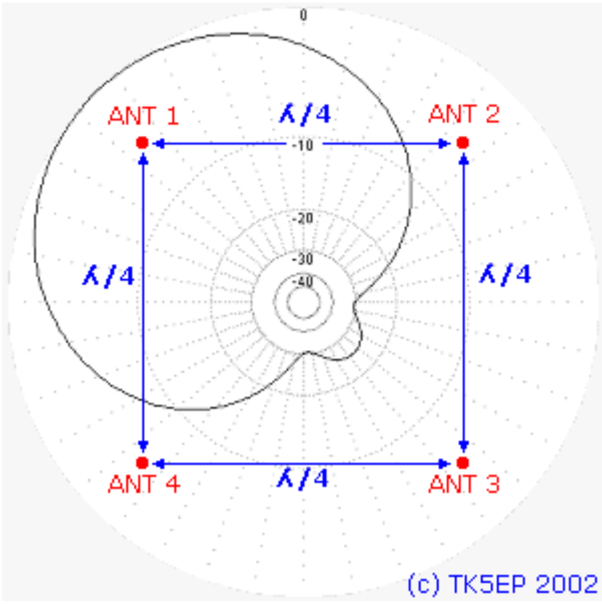


Diagram of the phaser and control box

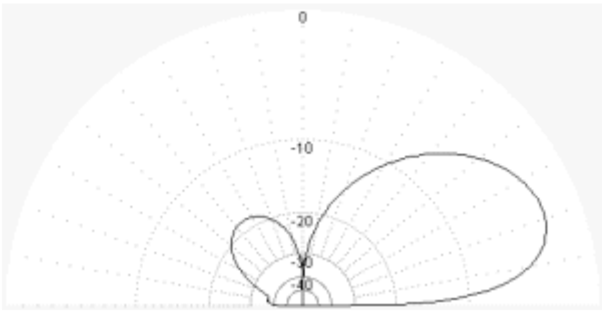
Directions, phasing and relay powering							
Direction	**K1**	**K2**	**K3**	**Ant 1**	**Ant 2**	**Ant 3**	**Ant 4**
NW	1	1	1	180°	-90°	0°	-90°
NE*	0	0	0	-90°	180°	-90°	0°
SE	1	1	0	0	-90°	180°	-90°
SW	0	0	1	-90°	0°	-90°	180°

(*) is the default position, with no supply. It should be your favorite working direction.

RADIATION PATTERN



Azimuth and position of antennas, system in NW position.



Elevation pattern.

The hybrid coupler, if well built, will deliver equal voltages on the 2 output ports as well as negligible voltage on the isolation port. The phase shift between both outputs is 90°.

This is only true if the impedances of the loads on all ports are the same as the one for which the system has been calculated. And this is in practice never the case ! So, the complete system is a compromise...

A 4 square array needs equals currents on each antenna to work properly. Unfortunately, the antenna impedances are NOT equal, varying on each antenna due to mutual coupling as well as during beam direction change. Feeding the antennas through feed lines that are 1/4 wave long or an odd multiple of a 1/4 wave long, will force the the antennnas to have the same currents in them even though they do not have the same feed point impedance. That's called current forcing.

Feeding the antennas with 1/4 wave long feed lines is very important !

The switching box can drive a 4 or 2 antennas phased array.

With 4 antennas, arrays are mounted in a perfect square with 0.25 lambda side, the beam directions are along the diagonals.

The phasing lines are quarter wave of 75 Ohm coaxial cable. Use at least a cable with 0.76 velocity factor, otherwise with 0.66 factor the lines will be too short to run to the center of the square (where the phasing box should be) with a quarter wave. Otherwise, you will have to cut the lines 3/4 lambda long.

I used CATV distribution coaxial cable with foam dielectric which can be easily found.

With 2 antennas, use antenna outputs 1 and 4. The corresponding position on the control box are NE and SE.

In this case, the phasing lines are quarter wave of 50 Ohm coaxial cable. Same remarks as above concerning the dielectric. Preferably use foam dielectric cables, this will make the lines a bit longer, enabling an easier connection.

Beam directions are in the alignment of the antennas and only 2 directions are possible.

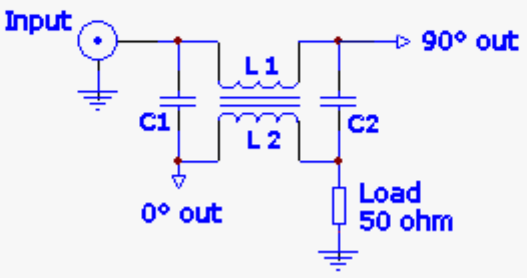
The feeding line to the station is a 50 Ohm coaxial of any length.

CONSTRUCTION DETAILS

Calculating the values of the hybrid coupler.

The T1 transformer is the "key" of the system. It is a Collins hybrid coupler build on a toroid core. Any core dimension can be used depending of the power you want to use. The colour must be red as it determines the permeablilty and frequency range.

The values of the hybrid coupler are :



$$X_C = \frac{1}{2\pi FC}$$

$$\Rightarrow C = \frac{10^6}{2\pi F X_C}$$

$$X_L = 2\pi F L$$

$$\Rightarrow L = \frac{X_L}{2\pi F}$$

Where Xc = 100 ohm, XL = 50 ohm , L in µH, C in pF, F in MHz, C1=C2 and L1=L2

From this, we can calculate the components for the different bands :

Freq.	C	L
1,850 MHz	860 pF	4,30 uH
3,650 MHz	436 pF	2,18 uH
7,050 MHz	225 pF	1,13 uH

Now, we have to build the T1 transformer.

The number of turns for a toroid coil is calculated with the formula :

$$N = \sqrt{\frac{L}{A_L}}$$

L in µH
N in turn
AL in nH/turn^2

So, for the above calculated value of 1.13 µH and a T225-2 which has a AL value of 12 nH/turn, it gives: 9.7 turns. (in practice 10 turns)

For an T225-2B core and an Al=21.5 nH/turn it gives 7.25 turns. (i practice 7 turns)

A turn is when the wire goes through the center hole of the core.

CAUTION: Be careful, some manufacturers give the AL in uH/100 turns!

In this case, you must use the following formula and units:

$$N = 100\sqrt{\frac{L}{A_L}}$$

L in µH
N in turn
AL in µH/100turns

You can find a nice free tore calculator written by DL5SWB on his page that will help you to calculate the right number of turns depending of your toroid choice.

The first step is to wind the coils with the 2 wires tighten together and measure their values. Solder the ends of both wires, and start to wind one turn of the first wire, then the 1st turn ot the second wire, and repeat for all turns. I've found that it's easier to make 1 of 2 more turns and measure the inductance. You can then easily adjust the coil to the right value by removing a turn or 2 and stretch or compress the windings on the core. Once you have the right value, lock the wires with varnish or tape.

Then, you must measure the capacitance between both wires. This value has to be substracted by half from the above calculated value of C1 and C2.

Then solder the 2 capacitors C1 and C2 of this calculated value. I generaly use 2 or 3 capacitors in parallel for C1 and C2, by choosing the right values and tolerances, you can trim to the the right value.

Finaly, using at least an oscilloscope (dual trace) and a wattmeter you can check if the phase shift of 90Ý is correct between both outputs, and if the power are the same. You can of course use better instruments if you have them !

Don't forget the load all ports with 50 ohms loads !

In practice, the 90 degree phase shift remains relatively constant over a large bandwith while the coupling energy of -3dB equal split between the output ports occurs only within a relatively narrow bandwith.(few percent of the design frequency)

The T2 transformer serves as a 180° shift line and is the same as T1.

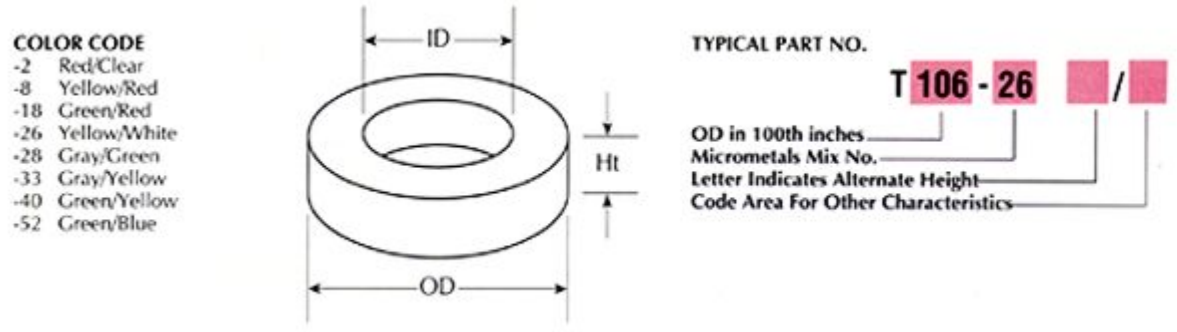
Wind the transformer with 2 wires tighten together. Ground one end of one wire and the opposite end of the other one. This will make a 180° phase shift.

The 180° phase shift can also be made with a half wave long coax cable. When cutting the coax, don't forget the velocity factor which will make the cable much shorter. (See the coaxial page of this site for coaxial datas)

I used ceramic capacitors of 1 kV rating and Teflon insulated wire for a 1.5 kW level. The relays must be able to handle your output power.

CHARACTERISTICS of the FERRITE CORE used in this SWITCH

DIMENSIONS							
MICROMETALS Part No.	**A_L nH/N^2**	**OD mm**	**ID mm**	**Ht mm**	**cm**	**A cm^2**	**V cm^3**
T225-2	12.0	57.2	35.7	14	14.6	1.42	20.7
T225-2B	21.5	57.2	35.7	25.4	14.6	2.59	37.8



Datas taken from Micrometals, Inc. © 1998. A lot of information about cores can be found there !

RECOMMENDATIONS

- Make the 4 antennas as similar as possible, use the same number of radials, same tubing diameter, etc...
- Carefully cut the 4 quarter wave phasing lines in the same 75 Ohm coax cable and as accurate as possible. Don't forget the velocity factor which depends of the cable you are using. I've measured some non neglegible differences between several manufacturers. I used a spectrum analyser with tracking generator to cut the cables to accurate phasing angle, but simpler methods are possible.
- Be sure to mount your system in the right shape and direction, don't forget the antennas fire along the diagonals. You can of course shift the whole system to have 4 other directions.

RESULTS

If you take care on all the above points, you will have very nice results with this antenna.

The F/B ratio is at certain time well over 25-30dB depending of the signals incoming radiation angle. The noise level on this antenna is much lower than with a single vertical and beam switching is done in a second.

The power dissipated in the load is at resonance, only a few percent of the input power. We found 15 W for more than a kW !

Plots have been made with the freeware software MMANA by JE3HHT which can be found here.