CIRCULAR POLARIZATION

VHF AND UHF CIRCULAR POLARIZED ANTENNAS TO WORK HAM SATELLITES

When we begin as a ham we usually have a mobile station or perhaps a vertical antenna with an HT or a FM transceiver at home. Later we listen to other hams speaking about horizontal polarization and perhaps, we later know somebody who works with circular polarized antennas.

But many hams do not know that our grandfathers only have worked with horizontal polarization and AM home-made transceiver for years. When technology made enough progress to reduce the transceivers size, but still with valves, they began to install them in the cars. Then a problem arose, How could they install an horizontal polarized antenna on the roof car?.

The technology went on making progress and the VHF and higher frequency transceivers began to emerge. To extend the coverage they installed repeaters and they were forced to do it with vertical polarization to make the access easier for the mobile stations. They discovered that colineal vertical no-directional antennas were easy to build in the higher frequencies which was unthinkable in the low bands.

We must take into account that horizontal and vertical polarizations are in relation to the radiant element is perpendicular or parallel to the earth surface, and both are linear polarizations.

When hams became to work with spatial communications, the first satellites had linear polarized antennas (They did not know other polarizations). These primitives spacecrafts did not even have aiming systems to point to the earth. As we can understand the polarization was changing and producing strong fading, specially when the linear antenna was pointing at the earth where it has a radiation null.

Later, orientation systems by magneto-torques were included to keep the satellite main axis aiming at the earth. These devices generate magnetic fields which let keep the orientation in relation to the earth magnetic fields and so to the earth surface. Then the antennas were installed with the maximum gain to the earth surface. But after solving this problem they realized that the rotation around the main axis was strong, to solve this problem was and is very difficult due to the absence of friction in the outer space. So they only succeeded in reducing this movement.

We must add that when the electromagnetic waves go through the atmosphere they must face to the ionosphere which has a strong electric charge. All of us know that thanks these layers HF communications are possible taking advantage of these low frequencies do not have enough energy to go through these layers and then they bounce against them and the earth surface several times. However satellite communications must use higher frequencies with more energy to go through them. But these higher frequencies have to pay for it a tax, this tax includes losses which attenuate them and they must face to other less known effect by means of which the waves suffer changes of polarization in a random way impossible to predict.

To work satellites, the terrestrial stations must have an antenna system which lets receive whatever kind of polarization with the minimal attenuation. We quickly think about a set of antennas with different polarizations so we could choose the most suitable in each moment, it will be that the best agree with the polarization from the satellite.

Whatever constant frequency signal which goes through the atmosphere is received with a changing polarization in the time. This means that if we could see in a vector shape the level and angle or phase of this electromagnetic wave in the time, in this case in a cycle, this vector will draw with its tip an ellipse. If this vector changes its sense but not its direction in the time it will produce linear polarization, this is an ellipse with one of its axis equal to zero. If this vector turns 360º in a cycle of its frequency with constant level, it will produce circular polarization and if the level is changing, which is the most common, it will produce elliptical polarization. Then whatever polarization is a kind of elliptical polarization.

	VERT.	HORIZ.	R.C.P.	L.C.P.
0	↑	0	↑	↑
¼ λ	0	→	→	←
½ λ	↓	0	↓	↓
¾ λ	0	←	←	→

TABLE "A": Pure polarizations

We can conclude that circular polarization will let us receive with less fading the changing polarizations. An option is to set two linear yaguis 90º each other with different feed lines and a switch, so we could choose the best polarization every moment, reducing the fading. This couple of yaguis could be set whatever angle in relation to the earth surface, but hams usually place them horizontal and vertical to take advantage of them in terrestrial communications. This system only has a drawback, we must change frequently the polarization to reduce the fading.

Nowadays we can find two methods to generate circular polarization with antennas, one of them is to built them mechanically in such a way that its radiation pattern is inherently circular, this is the case of Helix antennas. They generate a nearly perfect circular polarization, if they work in the resonant frequency. The other way is to use two linear polarized yaguis set 90º each other and to connect them properly phased to generate circular polarization. This last option generates a less perfect circular polarization. The feature which defines the perfection of a circular radiation pattern is the ellipticity.

But circular polarization can be Right Circular Polarization (RCP) or Left Circular Polarization (LCP), it depends on the vector is turning clockwise (CW) or counter clockwise (CCW) in relation to the time. Ham satellites are experimental devices and as time goes by they have been built with linear and circular polarization, and the last straw, with RCP and LCP.

Anybody knows that the yagui antennas are phased with the same phase and polarity to produce more gain, if we double the yaguis we get an extra gain of 3dB. In the same way, if we set a couple of yaguis 90º each other and we phase them to produce circular polarization, if we try to receive a linear polarization we will receive it with 3 dB less than the circular polarization, because the whole behaves as if we were receiving it with only a yagui.

Anybody also knows that if we are receiving with linear polarization, vertical for instance, and somebody is transmitting with the opposite linear polarization, horizontal in this case, we will receive this signal with between 18-20 dB less. This is the same case when somebody is receiving with RCP a LCP signal or vice versa. In any case it turns out to be between 3-4 smiter signals. It means that with weak signals, if the polarization is not properly matched we will not receive our correspondent.

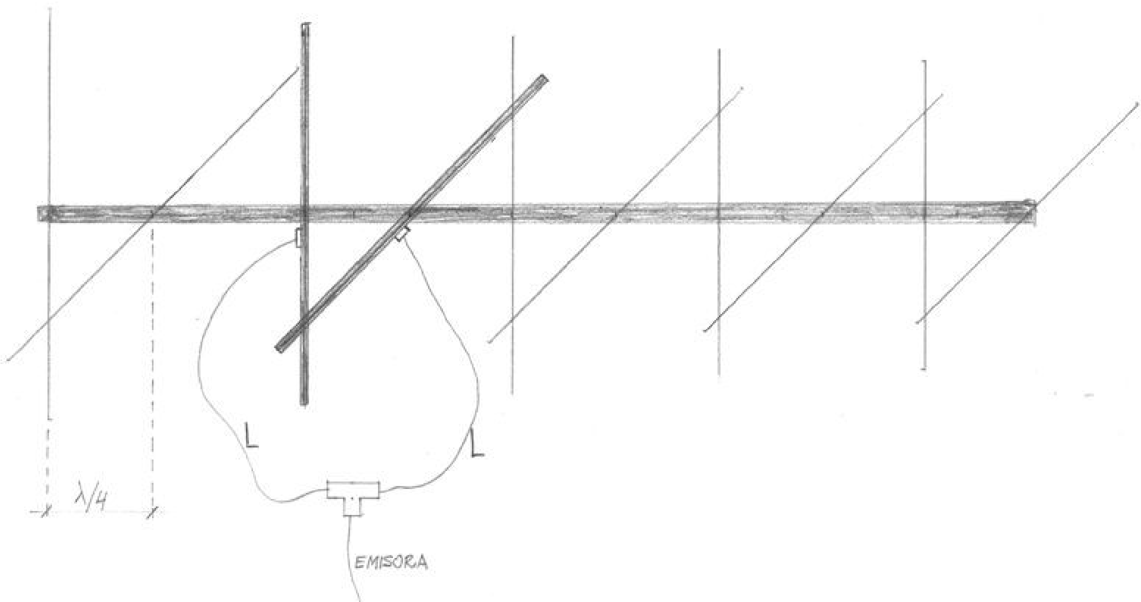

Figure nº1 Two yaguis mechanically set one of them 1/4λ forward in relation to the other and fed electrically in phase.

With all the above knowledge, the best antenna to work satellites will be a circular polarized and capable to switch between RCP and LCP. The whole will drastically reduce the fading and we will need to do the minimal switching between the different polarizations.

When I have spoken about Helix antennas before, I have affirmed that they are mechanically built to carry out its task. It means that if a Helix antenna is built with RCP it will never change to LCP by means of phasing lines. So we must have two helix antennas, one of them RCP and the other LCP and to switch between them. However two linear yaguis are more flexible because if we change the phasing lines we will get any kind of elliptical polarization.

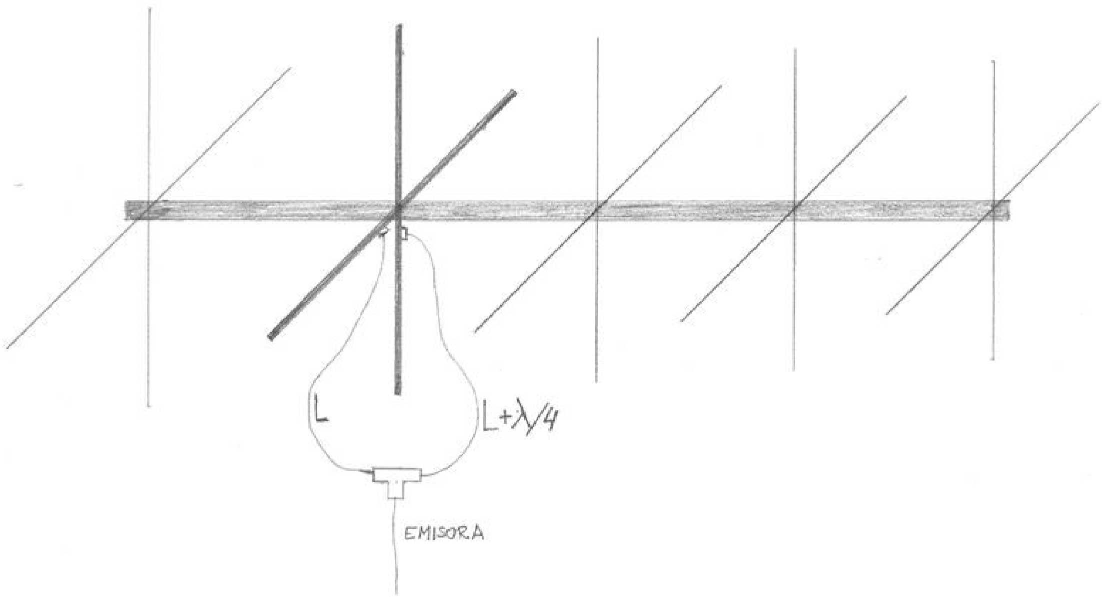

Figure nº 2 Antennas phased electrically by means of setting ¼ λ phasing line longer or shorter in one of the antennas

To sum up, and taking into account that anything in this live is a compromise, the kind of VHF and UHF antennas which will give us more satisfaction in spatial communications, will be two yaguis set 90º each other with the proper phasing lines to produce circular polarization. Furthermore we must install the necessary RF switches to change between RCP and LCP.

Now we are going to concentrate on the way to produce circular polarization with two yaguis. We can find two ways:

1.- Mechanically, we must place the two identical yaguis 90º each other, one of them 1/4λ forward in relation to the other and then the two yaguis will be fed electrically in phase (two identical pieces of feed line).

2.- Electrically, we must set the two identical antennas 90º each other, but in the same place, so we will phase them placing a piece of feed line 1/4λ longer or shorter in one yagui than in the other.

In the option nº1 the boom is 1/4λ longer than in the option nº2, so almost always the second option is chosen by the manufacturers.

At this point I would like to make clear some things:

1.- Mechanically is impossible to set two yaguis 90º each other in only one boom with the elements in the same plane, because each element of one antenna will cross the equivalent element of the other. So it will always exist mechanically a little gap which we will name "K", so the phasing lines will not be exactly 1/4λ, we must add a "ΔL". Each manufacturer will study this detail and they will offer us the best phasing lines.

2.- Although we could build the perfect phasing lines speaking about its length, What about the impedances?. So these phasing lines must carry out this task too. The phasing lines usually have an impedance different from 50 Ohm depending on the radiant configuration.

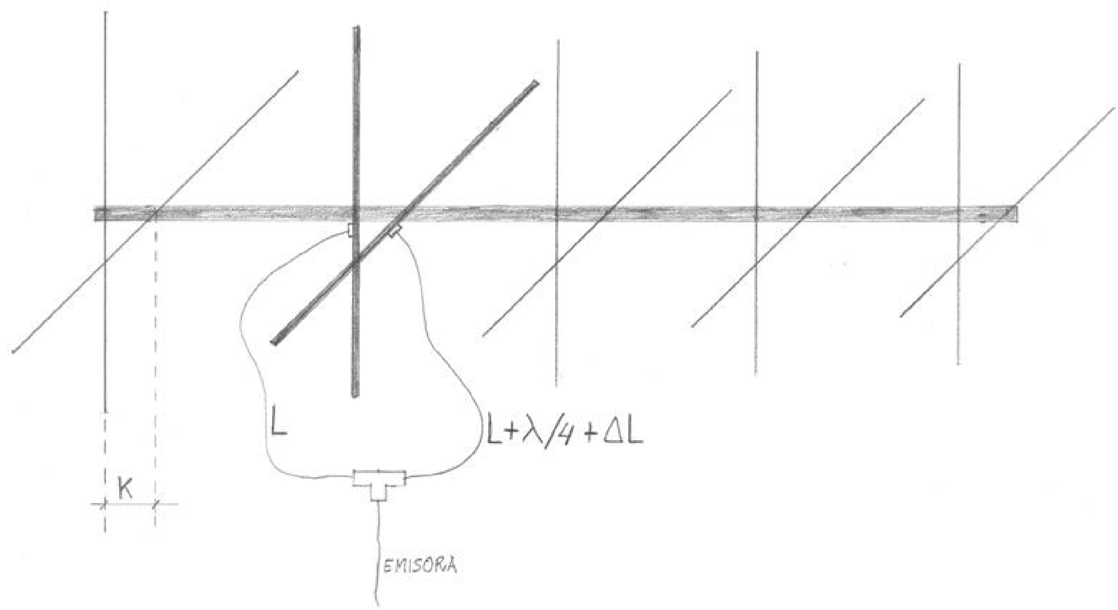

Figure nº3 Antennas mechanically phased taking into account the mechanical error, it is compensated by a "ΔL" in one of the phasing lines.

3.- All kind of yaguis are not suitable to carry out this task. They must have a symmetrical fed radiator, so the Gamma-Match system is not suitable for this task, it will produce a distorted circular polarization.

I do not have the intention of making you feel frightened, after all it is possible to home-build this kind of antennas, but I have to affirm that achieve the perfection taking into account all these details is a very hard work. The manufacturers take care to optimize their antennas by means of computer and they do the best to build mechanically all the elements, phasing lines and RF switches in the best way. Furthermore some manufactures pursue the perfection trying to improve small but important details, for instance they isolate the elements to avoid noise due to bad contacts for rusting, other even supply isolated fibber glass horizontal tubes or advice the way to set the feed line to avoid distorting the circular polarization. The antennas are usually set crossed with any element parallel to the earth, it is to avoid the birds perch on the elements.

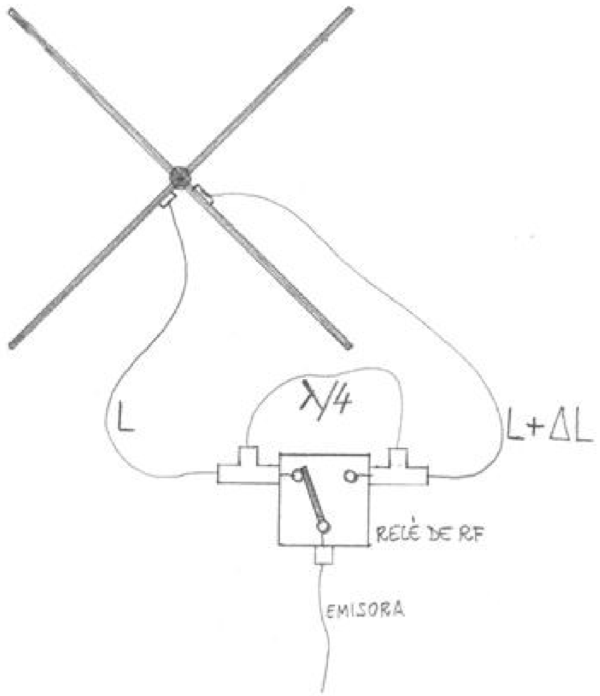

Figure nº4 Phasing system with an RF switch to get RCP and LCP

You can see below two tables for VHF and UHF bands in which you can see circular polarized antennas of the most known manufactures that you can easily find in the market, some of them even offer antennas optimized for the satellites band (145.800-146.000 MHz and 435.000-438.000 MHz). Of course, you can find more details, I have only chosen the most useful to take the proper decision in the case you have doubts to pick one up.

I will make some comments about the manufactures, but only about some interesting features which could be useful to make a decision about meeting your needs.

Hy-Gain only have a model per band in the market, you can purchase them separately or the whole which includes the horizontal fibber glass to join both yaguis. These antennas bring from the factory the RF switches to change between RCP and LCP. It is very difficult to install commercial RF switches because the radiant elements do not have connectors, the phasing system is made exclusively for this antenna. These antennas are optimized and designed to work satellites and they carry out its task properly. http://hy-gain.com.

COMPARATIVE OF VHF CIRCULAR POLARIZED YAGUIS

BRAND	MODEL	ELEMENTS	LENGTH M.	SURFACE M2	WEIGHT KG	GAIN dBd	GAIN - F/B dBd	RAD-H °	RAD-V °	POWER W.
HY-GAIN	216SAT	2*8	4,29	0,102	3,2	11,5	25			200-C/R
CUSHCRAFT	22XB	2*11	5,9	0,24	5	14	25			600-S/R
M2	2MCP14	2*7	3,2	0,102	2,72	10,2	20	52	52	1500-S/R
M2	2MCP22	2*11	4,74	0,23	7	12,25	25	38	38	1500-S/R
WIMO	18110	2*7	2,7		3,3	10	20	53	43	200/1200-C/R
WIMO	18111	2*10	4,7		4,3	12,3	25	38	35	200/1200-C/R
WIMO	X-QUAD	2*6	1,46		2,3	10,5	19	47	46	200/1200-C/R
DK7ZB	WX208	2*4	1,3		1,7	7	16	67	61	200/1200-C/R
DK7ZB	WX214	2*7	2,6		3,1	10	20	53	43	200/1200-C/R
DK7ZB	WX220	2*10	4,6		4,2	12,3	25	38	35	200/1200-C/R
DK7ZB	WX228	2*14	10,2		11	15	25	26	26	200/1200-C/R
F9FT	20808	2*4	1,03		1,2	6,9	16	31	86	1000-S/R
F9FT	20818	2*9	3,57		3,3	10,1	19	40	46	1000-S/R
F9FT	20822	2*11	4,62		4,2	11	25	37	41	1000-S/R

TABLE Nº1 COMPARATIVE OF VHF CIRCULAR POLARIZED YAGUIS

Cushcraft only have a model per band too, because although in UHF has a short model, it is not suitable to work in unfavourable conditions. This manufacturer offers RF switches to change between RCP and LCP as an option. http://cushcraft.com.

M2 has two models per band, both of them are suitable to work satellites, although the longer couple will give better performance. This manufacturer offers phasing lines to get RCP and LCP but no RF switches, there is no problem to adapt commercial switches to carry out this task. http://m2inc.com.

WIMO has two different models. We can find two classical yaguis per band, one shorter and the other longer. But he also offers the X-QUAD, one for VHF and another for UHF, they take advantage of the extra gain provided by the QUAD antennas confined to small booms. These antennas are really useful when we have limited space or we do not want to have problems with the winds or to spend money on strong towers. This manufacturer is the only who offers a switch box which lets change between the most useful different polarizations, Horizontal, Vertical, RCP and LCP, although I think it is only available for the UHF band. He offers RF switches to two different power out. So this is the manufacturer who offers more accessories, although he is not exactly the cheapest. http://wimo.de.

COMPARATIVE OF UHF CIRCULAR POLARIZED YAGUIS

BRAND	MODEL	ELEMENTS	LENGTH M.	SURFACE M2	WEIGHT KG	GAIN dBd	GAIN - F/B dBd	RAD-H °	RAD-V °	POWER W.
HY-GAIN	7030SAT	2*15	3,4	0,065	1,8	14	25			200-C/R
CUSHCRAFT	416TB	2*8	2,03	0,046	2,2	12,5	20	34	34	200-S/R
CUSHCRAFT	738XB	2*19	4,39	0,13	3,5	15,5	25	24	24	250-S/R
M2	436CP30	2*15	2,97	0,092	2,26	14,15	22	30	30	600-S/R
M2	436CP42	2*21	4,59	0,18	4	16,8	25	21	21	1000-S/R
WIMO	18207	2*10	2		2,5	11,5	20			200/800-C/R
WIMO	18208	2*18	3,4		3,5	14	20			200/800-C/R
WIMO	X-QUAD	2*9	1,27		1,6	12,8	21			200/800-C/R
DK7ZB	WX7020	2*10	2		2,2	11,5	20	42	36	200/800-C/R
DK7ZB	WX7036	2*18	3,4		3,1	14	20	30	28	200/800-C/R
F9FT	20438	2*19	3,25	0,09	2,2	13	24	29	29	1000-S/R

TABLE Nº2 COMPARATIVE OF UHF CIRCULAR POLARIZED YAGUIS

DK7ZB has four models for the VHF band and two models for the UHF band. It is not very difficult to find the model which meet your needs of gain and space. The manufacturer offers phasing lines for RCP and LCP and these antennas share the same WIMO RF switches. http://wimo.de.

F9FT offers three models for the VHF band and only one for the UHF band. This manufacturer offers a very complete instruction manual with all the necessary details to build your own phasing lines with different known feed lines of different velocity factors. He even offers how to connect four RF switches to achieve the most useful polarizations, Horizontal, Vertical, RCP and LCP. Without doubt this is a very didactic information if you have the intention of building your own switching system. http://f9ft.com.

I wish this information was useful to understand deeper this branch of the amateur radio, so my intention was to turn the satellites into a friendlier way so you feel attraction to them.

I am grateful to all hams who work this mode, for their patience when I am testing all kind of devices, and specially to Pedro EB4DKA because he infects us with its illusion and the effort he makes to keep updated his WEB http://eb4dka.tk. You can find all our experiences and even video recorders testing all kind of equipment.

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