

# "EGGBEATER" ANTENNA

## VHF/UHF ~ PART 1

ON6WG / F5VIF



For the enthusiastic listeners or the licensed amateur station wishing to experiment with satellite transmissions without investing a large sum of money in rotators and tracking systems, here is a very competitive antenna. It will appeal to those with no space for large arrays, or for those who simply wish to experiment with circular polarization for terrestrial transmissions.

### Introduction

This antenna was conceived mainly for high-speed digital transmission via satellite. Another reason was the need for a compact system due to the local environment of my station (mountainous region with high hills and obstacles too close to my station, no space to safely place rotative YAGI antennas).

If the horizon is unreachable for RF signals, that leaves only the sky above us.

To use the high-speed digital satellites, the level of signal reaching the TNC must be high enough to correctly decode the packets. For example, I mainly use an AEA/PK-96 TNC which requires at least 200 millivolts p-p at the input. To have this level when receiving 9600 Bd packets, there must be at least an S-3 showing on the S-Meter of my receiver.

### Design

The antenna is made of two full waves loops, mounted at right angles to each other. Then coupled together, 90 degrees out of phase over a horizontal circular reflector. With this configuration the antenna is omni directional and circularly polarized. Changing the feeder connection from one loop to the other loop will effectively change the polarization between RHCP and LHCP. The reflector gives a noticeable 'gain' as we will see later. Thus this design can be especially good for low earth orbiting satellites (LEO). ISS and PcSATS being good examples.

It is in fact an improved design of the 'Turnstile' antenna.

N.B. We will discuss vertical and horizontal field patterns for « Turnstile » versus « Eggbeater » later in this article.

At the horizon the polarization is linear and horizontal. As the elevation increases, the polarization becomes more circular, proportional to that increase in elevation.

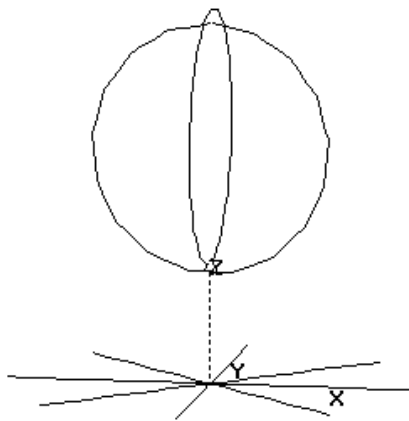
## Design and calculation

At VHF frequencies and above, the relation between the diameter of the loop and the diameter of the wire (or tube) that makes the loop, is quite small. The length of the circumference of the loop must be increased in relation to its wavelength. It is also dependent of the kind of material used . To build a VHF loop, 4% needs to be added to its original length. A UHF loop will require 10% added to the original total length.

Each of the two loops forming the antenna has an impedance of 100 ohms, and when coupled in parallel, they offer an ideal 50 ohms impedance. We will use the properties of a quarter wavelength coax line to achieve a 90 degree phase difference between the two loops in order to obtain circular polarization.

As the design is a derivative of the ' Turnstile ' antenna ( dipoles being replaced by loops ), we will use a similar ground reflector. The dimensions of which will be equal to those used for ' Turnstile ' antenna except for the distance between the loops and the reflector. The ' Eggbeater ' being spherical in shape, the reflector will be of circular design and made of at least 8 quarter wavelength radials. Distance between loops and reflector : 1/8 wavelength (best result issued by « 4nec2 »). The antenna design software ' 4nec2 ' ( outstanding ! ) was used to optimize and produce field patterns for the diagrams illustrating this article .

Note: Increasing the space between loops and reflector will result in a lower gain and a lower angle radiation pattern.



**VHF Eggbeater Calculation:** - Copper 2-mm diam. (0.08 in) was used for preliminary test.

- Flat aluminium rod 10-mm size (0.4 in) was used in the prototype.

Calculation of the loop length: The formula is  $1005 / F$  (MHz) which gives :

$$1005 / 145 = 6.93 \text{ feet ( or } 211,26 \text{ cm.)}$$

For safety, as the bandwidth of the antenna is quite wide, we can round the result up to 7 feet and fine-tuning the antenna during the test ( shortening is easier then lengthening ).

Phasing line: RG62 A/U quarter wavelength coaxial cable – impedance 93 ohms – VF = 0.86

Phasing line calculation: The formula is :  $246 \times \text{coax. velocity factor} / F(\text{in MHz})$

$$\rightarrow (246 \times 0.86 (\text{VF}) / 145) = 1.46 \text{ ft (or } 44.5 \text{ cm).}$$

**UHF Eggbeater Calculation:** - Copper wire 2-mm diam. (0.08 in) was used for preliminary test.

- Brass tube 4-mm diam. (0.16 in) was used in the prototype.

Calculation of the loop length:

$$1005 / F (\text{in MHz}) \rightarrow 1005 / 435 = 2.31 \text{ feet ( or } 70.4 \text{ cm. )}$$

For safety, as told above, we can round the result up to 2.35 feet and fine-tuning it during the test.

Phasing line: RG62 A/U quarter wavelength coaxial cable – impedance 93 ohms – VF = 0.86

Phasing line calculation: The formula is :  $246 \times \text{coax. velocity factor} / F(\text{in MHz})$

$$\rightarrow (246 \times 0.86 (\text{VF}) / 435) = 0.486 \text{ ft (or } 14.8 \text{ cm).}$$

## Field Pattern diagram

The diagram below shows the field pattern of an 'Eggbeater' antenna over a perfect ground reflector.

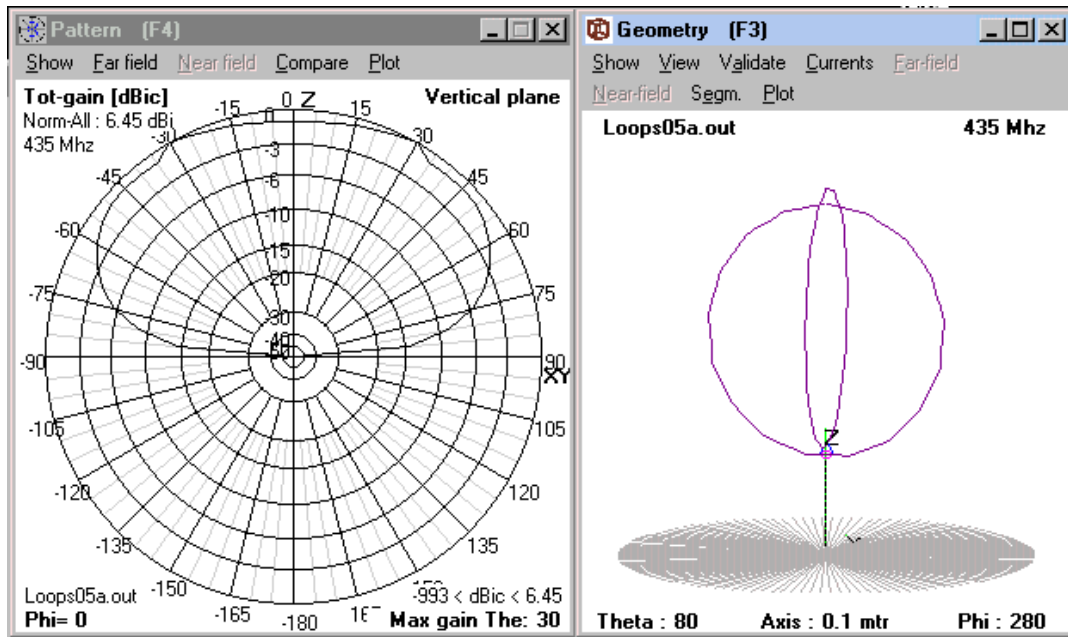


Fig 1 'Eggbeater' over a perfect ground reflector (spacing is 1/8 wavelength)

The next field pattern shows the 'Eggbeater' antenna over an average ground reflector (soil). A dramatic change in the field pattern appears due to the poor reflecting properties of the ground. As a matter of fact, the first case favours high and very high radiation angles ( from 30 to 90 deg.). The second case favours low radiation angles. This was confirmed at the time of the prototype test ( See ' Practical tests and results ' column).

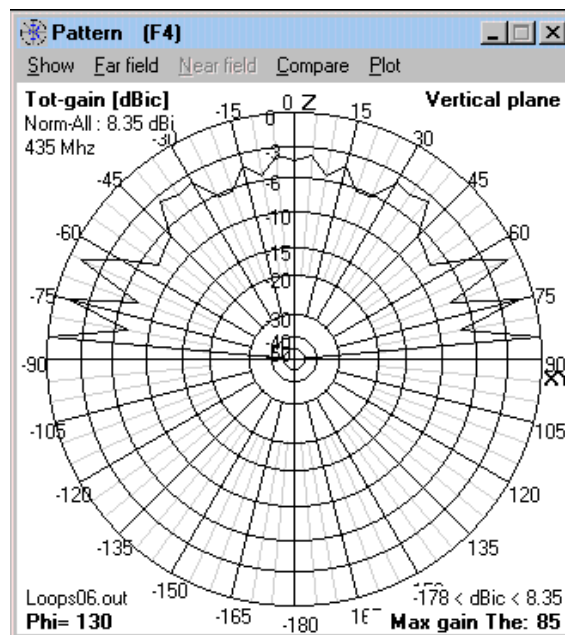


Fig 2 'Eggbeater' antenna with 8 radials over an average ground. Height of the antenna : 5 m.  
On 70 cm with only 8 radials, the ground has still some effect on the field pattern

In Fig 2, under a vertical angle of 25 deg. one can see clearly the increase of the gain which is passing from 3.76 dBi ( maximum value fig 1) to +/- 8 dBi (maximum value fig 2) as well as large losses over 30 deg.

To improve the field pattern of the antenna and to approach as much as possible to the Fig 1 diagram, the reflector must be covered with a thin aluminium lattice ( the one used for mosquito screen is perfect ) or one can use also an aluminium, or better, a copper disc.

The diagram below shows the radiation field pattern of the classical 'Turnstile' antenna. Fig 3 allow us to compare 'Eggbeater' versus 'Turnstile' antenna.

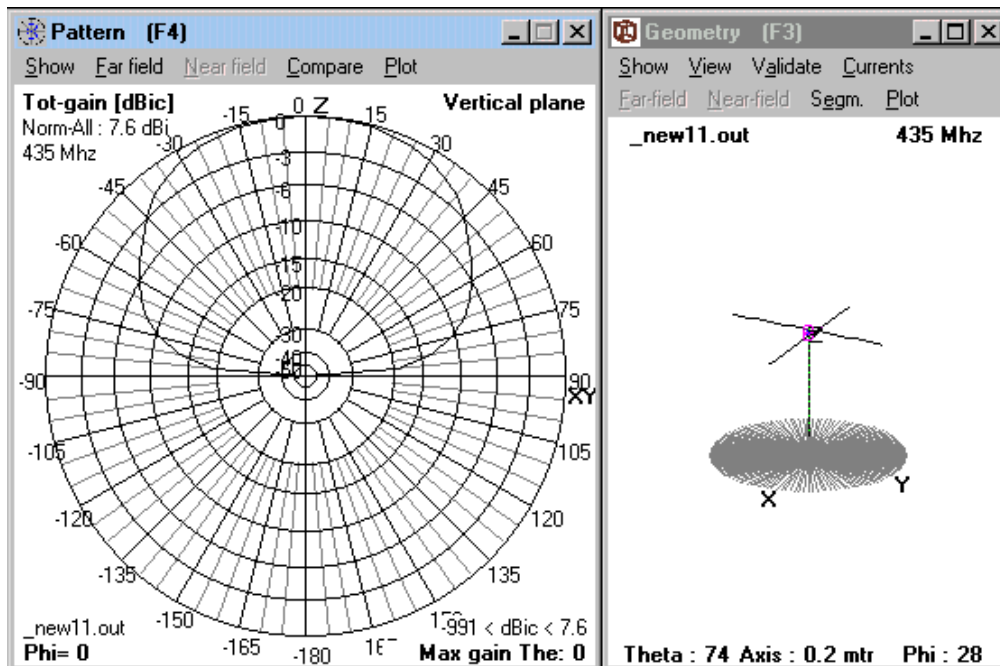


Fig 3 'Turnstile' antenna over a perfect ground reflector.

### 'Eggbeater' versus 'Turnstile'

- A comparison between diagrams shows that the 'Turnstile' antenna favours rather high vertical angles (55 to 90°) while the 'Eggbeater' antenna favours intermediate vertical angles ( 30 to 55°). straight over the antennas (90°), there is a 2 dB difference in favour of the 'Turnstile' antenna. But at a vertical angle of 40°, there is a 2 dB difference in favour of the 'Eggbeater' antenna.
- The noise level produced by a loop antenna is well under the one produced by a dipole, rising favourably the signal / noise ratio.
- The gain of a loop is 1.25 dB over a dipole antenna.

One can come to the conclusion that performances of these two antennas are very close. For terrestrial transmission, low vertical angles are used, so according to diagrams results, the 'Eggbeater' antenna seems to be the best compromise.

d) Practical construction of the 'Eggbeater' antenna is more compact ( reflector to antenna distance is 1/8 wavelength in 'Eggbeater' design versus a 1/4 wavelength (minimum distance) in 'Turnstile' design.

A perfect match between antenna and feeder can be also easily reached on the 'Eggbeater'.

## Practical tests and results

70 cm Band : | 430 | 432 | 435 | 436 | 437 | 438 | 440 |  
SWR : | 1.3 | 1.2 | 1.0 | 1.0 | 1.1 | 1.2 | 1.3 |

2 M Band : | 144 ---- 146 |  
SWR : | 1.1 |

A SWR of 1.0 means that there was no deflection of the needle on the SWR meter.

## Receiving signals

Three satellites transmitting with distinct power were chosen for the proposed test.

- 1) GO-32 Power 1 W / Turnstile antenna / Circular polarization.  
9600 Bd digital transmission, freq. 435.225 MHz
- 2) LO-19 Power 400 mW / Turnstile antenna.  
Cw telemetry signals, freq. 437.125 MHz
- 3) CUTE-1 Power 100 mW /  $\frac{1}{4}$  wavelength monopole antenna / linear polarization  
Cw telemetry signals, freq. 436.8375 MHz

Level of received signals : ( with a 20 dB. Pre-amplifier and TS-9500 as receiver)

<u>Elevation :</u>	<u>0°</u>	<u>10°</u>	<u>20°</u>	<u>30°</u>	<u>40°</u>	<u>50°</u>	<u>60°</u>	<u>70°</u>	<u>80°</u>	<u>90°</u>
GO-32	S 0-1	S 1-2	S 2-3	S 3-4	S 4-5	S 5-6	S 7-8	S 8-9	S 9-9+20	S 9+40+
LO-19	S 1-->	S 5-6	S 6-7	S 7-8	S 8-9	S 8-9	S 9	S 9	S 9+	
CUTE-1	S 0	S 1	S 2	S 3	S 4	S 5	S 6	S 7	S 7	S 7

These measurements must be taken with circumspection as values are only correct for this configuration. However, the beginner will have a good idea of the possibilities offered by this type of antenna, because very frequently the 'S-Meter' is being the degree of reference of radioam's mind.

These results are also confirming the field pattern of the antenna.

## Signal computation

To know what kind of antenna we need to use to receive a fixed satellite, we can calculate its signal level arriving on the receiving antenna.

This is being out of the outline of this entry, the reader will refer with great interest to ' Predicting signal levels ' chapter in the ' Satellite Experimenter's Handbook ' ( Davidoff ) published by the ARRL ( Revised Edition ' The Radio Amateur's Satellite Handbook' ).

## Practical building

Practical building is left to the individuals own imagination . PVC water pipes and sleeves used by plumbers will provide a very convenient assembly system. Loops could well be attached to the side of a PVC sleeve that is closed by a cap, thus making the whole system watertight. Coaxial cable should then be connected inside the sleeve and the whole sleeve assembly can be fitted on to a length of PVC pipe, acting as a mast. A ' T ' piece can be inserted at the middle or bottom to extract the coax feeder.

N.B. Be warned that some PVC pipes have very poor dielectric characteristic in VHF or UHF. In this case, tuning of the antenna will not be possible e.g. high SWR, cannot find resonance etc...( it was the case here for the UHF antenna). If this is the case, the loops must be mounted on a better quality dielectric component.

## Practical building schematic

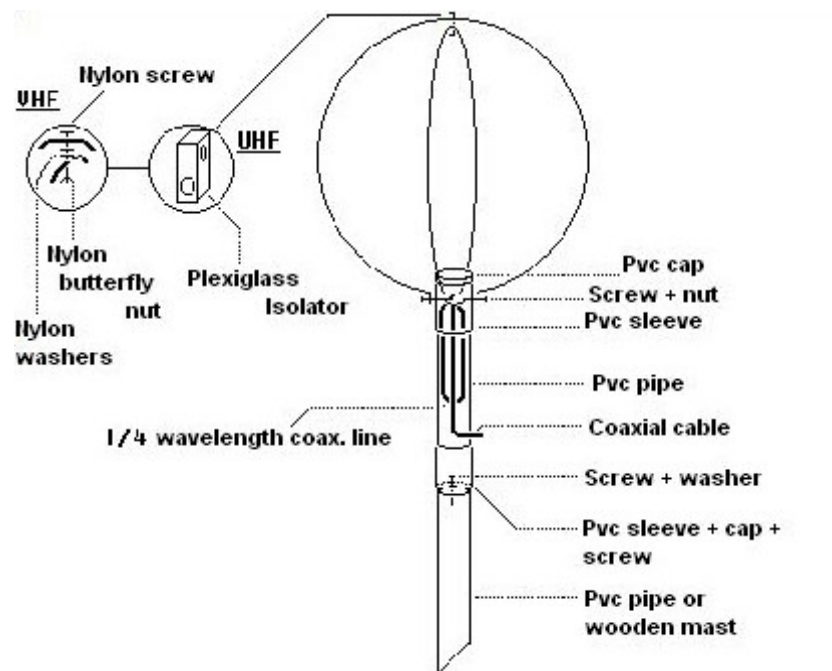


Fig 4 Practical building

The ground reflector is not shown to avoid overloading the schematic. But it is normally made of 8 aluminium radials connected to only one central point and obligatory covered with an aluminium lattice ( the type for mosquito screen is perfect ). The reflector will be attached to central mast supporting the antenna itself. Radials can be attached around the mast simply using a stainless steel clamp.



Fig 5 'UHF Eggbeater Antenna'

The VHF model can be strengthened by adding a vertical PVC pipe of around 1 cm diam. in the middle ( See Fig 6 below ).



Fig 6 ' VHF Eggbeater '

**Terrestrial traffic**

Tests conducted to listen to vertically polarized terrestrial stations have shown the superiority of the ' Eggbeater ' over a half-wave vertical antenna. The ' Mount Revard ' VHF repeater situated about 37 miles away has a S-5 report on my 2m vertical half-wavelength antenna and a S-9 report on the ' Eggbeater ' antenna. The vertically polarized ' Beaujolais ' UHF phone repeater situated about 53 miles away to the north cannot be used using a vertical collinear antenna, his signal is also S-5. With the UHF ' Eggbeater ' antenna, his signal is over S-9 and it can be opened and used at any moment. Several other tests were also conducted with horizontally polarized terrestrial stations. Results were also very good. As the antenna is circularly polarized it is very easy to work vertically polarized stations as well as horizontally polarized stations without any polarization change.

**Right Hand Circular Polarization : schematic and connections**

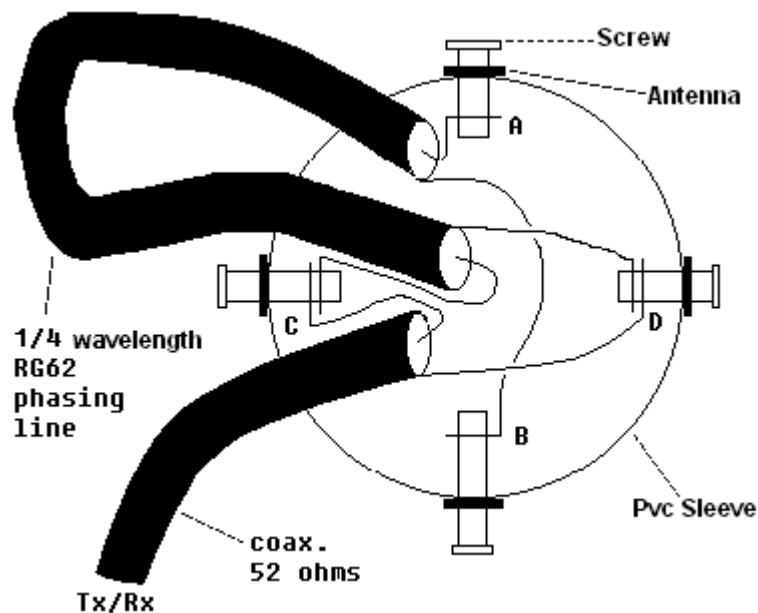


Fig 7 ' Eggbeater ' antenna, bottom side, looking vertically to the sky.



### **Polarization interchange by switch or relay**

( See details in the ' Eggbeater Antenna ' Part 2 ).

We can easily switch from RHCP to LHCP by connecting a manual coaxial switch or a coaxial relay switch at C and D ( Fig 7 ).

But we have to know that, in general, when a received signal is inverted, the difference will not be more than 30dB. Furthermore, except in some special cases, duration of inverted signals are often short. So, having an antenna equipped with a polarization interchange system is not essential. It is just an advantage.

Results shown in the table ' Level of received signals ' ( page 5 ) were taken using RHCP only.

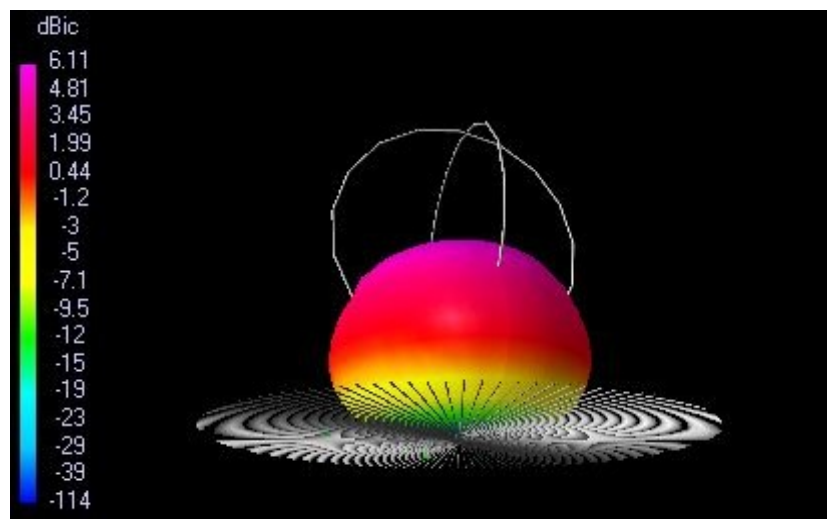
It must be known also that the polarization of some satellite will appear inverted after their pass at the zenith of their trajectory related to the receiving terrestrial station.

Explanation of these phenomenons can be found in the ' Satellite Experimenter Handbook ' or in the new Davidoff's edition ' The Satellite Handbook ' ( see « Bibliography and Appendix » rubric).

### **Conclusion**

The antenna can still be improved.

The horizontal field pattern is not exactly circular, but very slightly elliptical. This is first due to the feeding system that is unbalanced ( coaxial cable ) while the loops are balanced. To solve this problem the use of a balanced phasing section for coupling the loops is necessary. A BALUN would be also used to have a perfect balanced field pattern. Ferrite cores placed around coaxial line could be used for this purpose.



Remark : The web page below contains an accurate “loop calculator” and relevant advice about construction of loops for VHF and higher frequencies. The calculator is also a converter between feet and meters or centimeters. To visit the page click on the blue link.

<http://mysite.verizon.net/ka1fsb/loopcalc.html>



## **Bibliography**

The following works were useful to choose and elaborate this high performance, low budget antenna.

Pages and editions are not reported because page numbers can differ from one edition to another. Only chapter's titles have been kept.

Antenna Book.....(ARRL)..... link to : [The-ARRL-Antenna-Book](#)  
Chapter.....Wave attenuation  
    VHF propagation beyond line of sight  
    Reliable VHF coverage ( path loss )  
    Matching devices at the antenna : the quarter-wave transformer  
    Quad : dimensions for VHF / gain

The Satellite Experimenter's Handbook (Davidoff) (ARRL).  
(or Revised Edition 'The Radio Amateur's Satellite Handbook)  
Chapter..... Delay and phasing lines  
    How to change sense of polarity ( Polarization ; Sense)  
    Calculating EIRP ( Gain and EIRP)  
    Predicting signal levels  
    Predicting relative link signal levels  
    link to : [The-ARRL-Satellite-Handbook](#)

( [Click on the blue link to visit the website.](#) )

To design and create field pattern diagrams, the following software was used :

4nec2.....by Arie Voors.....<http://home.ict.nl/~arivoors/>

Satellites informations :

GO-32 ..... <http://www.amsat.org/amsat-new/satellites/satInfo.php?satID=14>

LO-19 ..... <http://www.lusat.org.ar/>

Cute-1 ..... [http://lss.mes.titech.ac.jp/ssp/cubesat/index\\_e.html](http://lss.mes.titech.ac.jp/ssp/cubesat/index_e.html)

Commercial manufacturer :

M2 Antenna Systems, Inc..... [www.m2inc.com](http://www.m2inc.com)

## **Aknowledgements**

Special acknowledgement to Arie Voors for his excellent software and for his help to the ' 4nec2 ' users in case of need.

Special thanks also to Nigel, G4DCQ, for his comments, suggestions, and improvements to the English text.

## Appendix

French translation of this article :

Traduction française de cet article : <http://www.on7wr.be/Gigazette/ON6WG/eggbeater.pdf>

Since May 2009, this article is also available in Spanish. It was published by the Spanish magazine "Radio-Noticias" ( issue number 198 ).

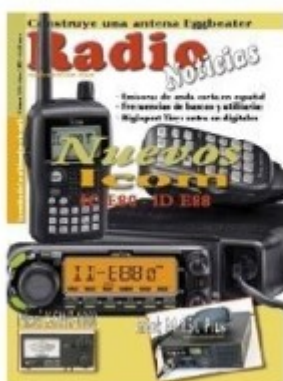
Desde mayo de 2009, este artículo también está disponible en Español.

Fue publicado en la revista española "Radio-Noticias" ( Número 198 ).

<http://www.radionoticias.com/>

Radio-Noticias de mayo

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Te presentamos los próximos equipos **Icom** que llegarán a España, un portátil (IC-E80) y un base-móvil (ID-E880), ambos bandas V-UHF y compatibles **D-Star**. Además, te mostramos todos los pasos para construir una antena Eggbeater de VHF o UHF y un choque balun para mejorar tus radiantes.

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