Patrick Lindecker (F6CTE)
Maisons-Alfort (France)
20th of June 2021 - Revision A

Study of an active antenna for LW and MW

CONTENTS

1. Introduction

Due to the very numerous references in French of the original paper, a translation in English is not possible. So this document is a summary of the following paper in French: http://f6cte.free.fr/Etude_d_une_antenne_active_GO_PO.pdf

A certain number of transmissions can be decoded in LW (Long Wave) and MW (Medium Wave), either Ham transmissions (as on 137 kHz and 475 kHz), or Utilities, especially the ones which can be decoded by the Multipsk/Clock programs, between 60 and 518 kHz.

The goal of this paper is:

- to introduce the LW/MW transmissions,
- to propose an active antenna for these frequencies.

2. Ham bands and Utilities frequencies in LW/MW

2.1 The “137 kHz” Ham band

It is a worldwide band also called « 2200-meter band », from 135.7 kHz to 137.8 kHz (see [1] for the band plan). The effective radiated power (ERP) is limited to 1 W, for a maximum power delivered to the transmitter equal to 500 W in France (the difference of power being lost in form of heat by the antenna).

As the maximum transmission power is 1 W and not 800 kW as for the Allouis (France) transmitter (time signal on 162 kHz), it follows that the reception level is extremely weak. Consequently, only narrow digital modes (let’s say ≤ 10 Hz), decodable at very low signal to noise ratio, as for example QRSS (slow CW), are used.

Apparently, there is no much traffic on this band (even at night). It seems that modern modes, as WPSR (dialed on 136 kHz), are more used than QRSS.

2.2 The propagation in LW

The transmission is only done by the ground surface (between the ground and the D layer), following the Earth curvature. This transmission is reinforced during night. On transmission, the polarization (electrical field direction) must be vertical. Indeed a horizontal polarization wave would be rapidly absorbed by the ground. The transmission vertical antenna must be the highest possible. To receive the maximum electromagnetic field, the reception antenna must be vertically polarized as a whip antenna or a loop antenna in the vertical plane.
Due to the ability for LW to penetrate ground, LW transmission systems are used in speleology.

The range, which increases with the surface conductivity, is around 1000 km, and even more if propagation is done above salt water.
However, if “d” is the distance between the transmitter and the receiver, it must be noted that the electric field decreases according to:

- 1/d at weak distance (normal decreasing in « far field »),
- $1/d^2$ at large distance, due to the ground absorption.

2.3 The “630 m” or “475 kHz” Ham band

There is another Ham band, in MW, located between 472 and 479 kHz and called « 630-meter band ». Some countries have an extension of this band. The digital modes used are the same as on 137 kHz. However, there is more traffic than in 137 kHz, for example in WSPR (receiver dialed on 474.2 kHz or 502.4 kHz, if permitted).

2.4 Utilities frequencies in LW/MW

It is possible to decode several Utilities with the Clock program for time signals, or Multipsk for other signals:

- 60 kHz : MSF, JJY and WWWB time signals
- 75 kHz : HBG time signal
- 77.5 kHz : DCF77 time signal
- 128.1, 134.6 and 138.0 kHz : IEC 870-5
- 147.3 kHz : DDH 47, RTTY 50 bauds
- 162 kHz : France-Inter time signal
- 198 kHz : BBC time signal
- between 191 and 285 kHz : NDB beacons
- between 283.5 and 325 kHz : DGPS stations
- between 490 and 518 kHz: NAVTEX.

3. Antenna selection

3.1 Introduction

The original paper compares three types of antenna:

- whip antenna,
- air loop antenna (see [2]),
- ferrite loop antenna (see [2]).

The first one is sensitive to the electric field whereas the second and the third ones are sensitive to the magnetic field.

3.2 Directivity of the loop antenna

Below, it is given the radiation pattern envelope for a circular loop antenna (air or ferrite one).

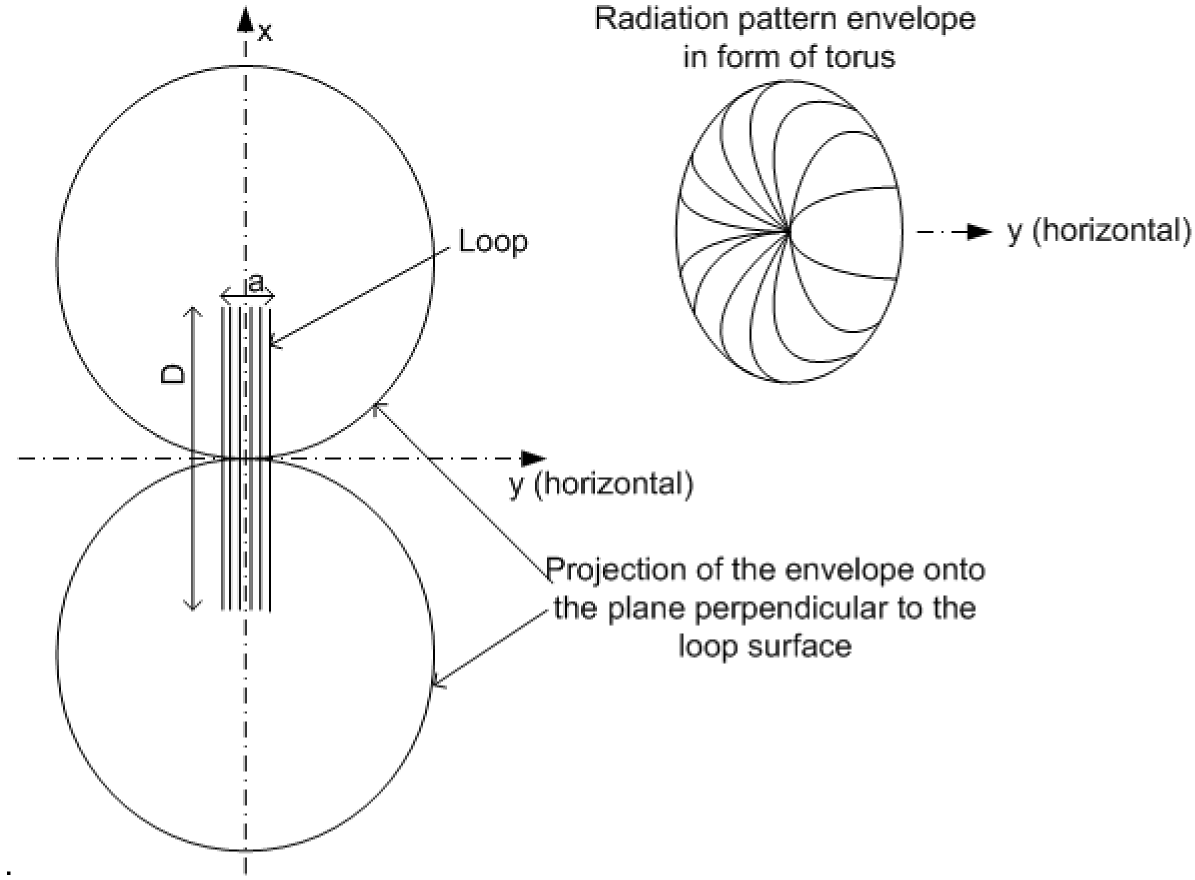

Figure 1

The best reception direction is horizontally, on the loop plane. Reversely, if the loop plane is perpendicular to the propagation direction of a transmission, the loop will not receive this one.

As the received electric field is vertical, the loop is necessarily vertical. Installed horizontally, the monitored signal becomes very weak.

3.3 Special case of the ferrite loop antenna

The ferrite concentrates the magnetic field lines. Schematically, we have (ignoring discontinuities):

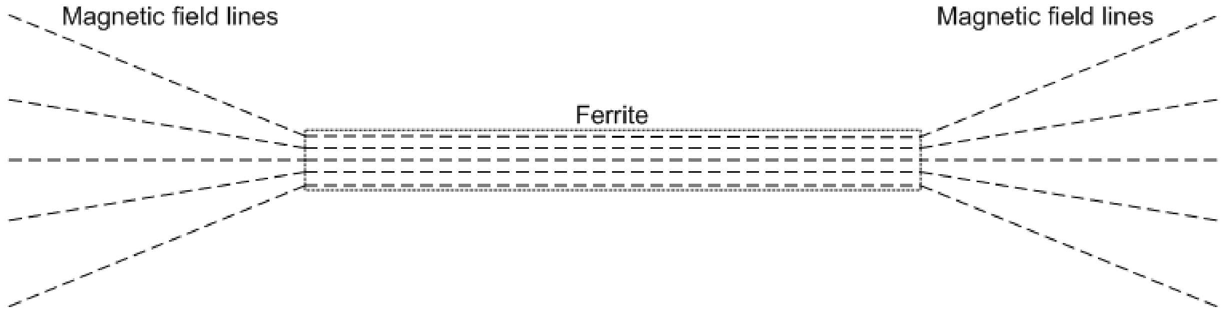

Figure 2

3.4 Selection on the antenna

The conclusion of the original paper is given below.

The whip antenna advantages are:

- it is not necessary to adjust a frequency (no resonant circuit),
- absence of horizontal directivity.

So the use of this antenna is simple.

Its disadvantages are:

- a risk of distortion due to the absence of selectivity,
- a sensitivity to human-made noise in town (in “near field”).

For a loop antenna, advantages and disadvantages are inverted compared to the whip antenna.
The loop antenna disadvantages are:

- it is necessary to adjust a frequency (the resonant circuit one). However, this selectivity permits to limit the signal + noise level,
- its horizontal directivity, which makes necessary for the user to direct the antenna.

Its main advantage is the absence of sensitivity to human-made noise in town (in “near field”, so through an electrostatic induction). Of course, in far field, there is no protection against noise (whatever its origin), as this noise pertains to the electromagnetic field.

The ferrite loop antenna is as good as an air one, provided that the signal is electronically amplified. Moreover, it is not bulky and can easily be directed.

Finally, the author, who lives in a city, chose a ferrite loop antenna.
Note that in the countryside, the choice could be a whip antenna.

3.5 Diagram of a loop antenna

The antenna is considered as a generator of induced voltage (e_{rms}) followed by the own impedance of the antenna, composed of a losses resistance Rl, the loop inductance Lloop, this set being set in parallel to the distributed parasitic capacity Cloop (see figure 3). Ci is the input capacity of the preamplifier. The inductive reactance is compensated by the Cv capacity, so that the Lloop / (Cloop+Cv+Ci) be tuned, thanks to Cv, on the desired frequency (f). The quality factor Q of the inductance is equal to Q=Lloop.2.π.f / Rl. The received bandwidth B_{-3dB} is narrow and equal to B_{-3dB}=f / Q.

This circuit increases the signal (and noise) voltage, this because at resonance, we have $U_i/e_{rms}=Q$.

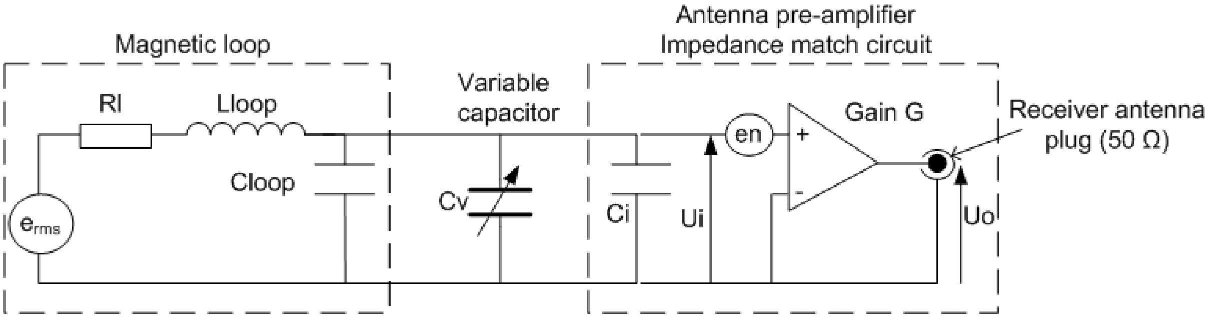

Figure 3

4. Amplification and impedance matching

4.1 General diagram

On Internet, it will be found different active antenna diagrams, for example in [3]. The author proposes, below, the general diagram of his active antenna.

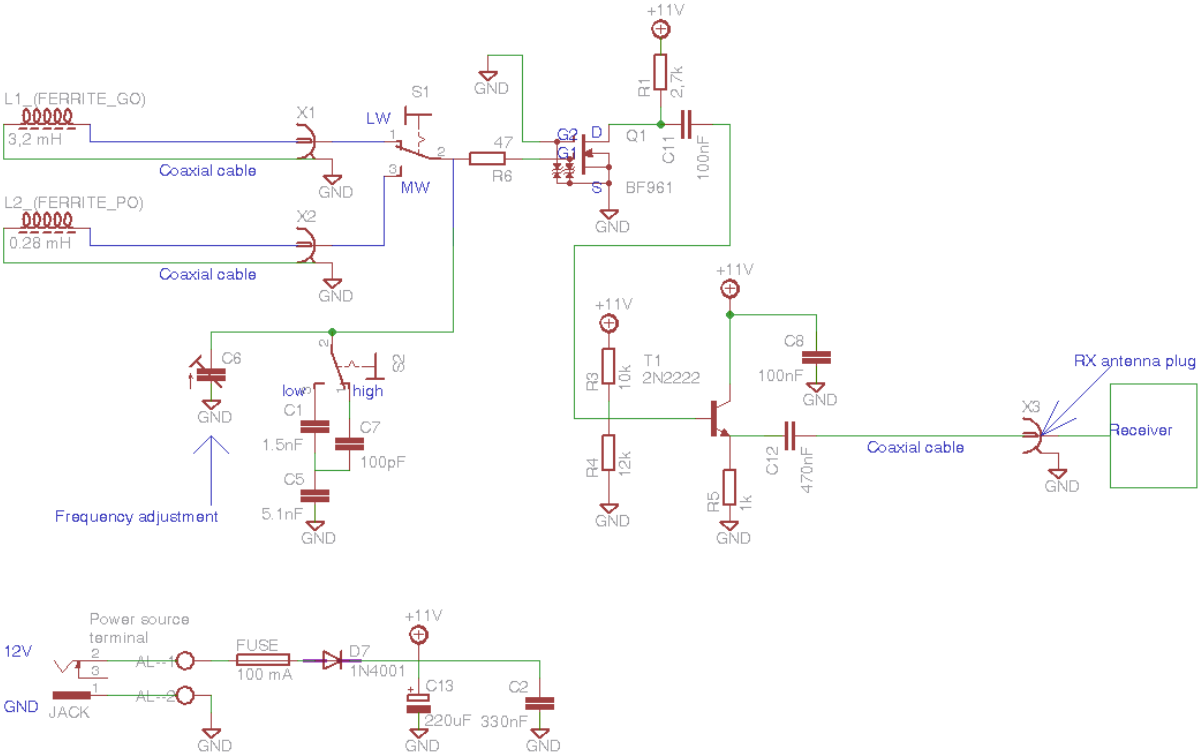

Figure 4

The goal is to cover the radio band from 60 to 518 kHz. It can only be done with two bands (LW/MW), each one divided in two frequencies blocks (« low » / « high »).

The inductance values (LW: 3.2 mH and MW: 0.28 mH) are the ones measured on the ferrite used by the author.

This diagram is inspired from the last diagram of [3], using what the author had on hand. The 12 V supply is supposed stabilized. Apparently, this pre-amplifier works from 5 V up to, at least, 13.8 V stabilized.
The first transistor, MOSFET (BF961), works in common-source (as an amplifier) with the G2 gate at 0 V. In this configuration, there is neither deformation nor saturation of the signal. The second transistor, bipolar (2N2222), works in common-collector (as a voltage follower).
The global voltage gain of the pre-amplifier (G) is about 3.

Both coaxial cables (50 or 75 Ω) between the ferrite and the LW/MW switch forms a shielding down to the metallic box containing the electronic circuit. They must not be too long (≤ 0.5 m), because they introduce a certain capacity (about 40 pF per m of coaxial cable), which is set in parallel to the variable capacitor (C6). Reversely, the coaxial cable length at the pre-amplifier output is not critical.

For the block of low frequencies (switch on « low »), the capacity of C6 (21 to 522 pF) is set in parallel with C1 and C5 in series (which forms a capacity of 1.16 nF).
For the block of high frequencies (switch on « high »), the capacity of C6 is set in parallel with C7 of 100 pF (in fact with C7 and C5 in series).

With these inductance and capacity values, it is found experimentally:

- LW / low block: 60 to 82 kHz,
- LW / high block: 81 to 202 kHz,
- MW / low block: 199 to 272 kHz,
- MW / high block: 268 to 551 kHz.

The amplifier is very selective as the quality factor is about 115 in “low” position and 55 in “high” position.

Due to the simplicity of this circuit, the author welded components on two pieces of copper strip plates (one for the supply and the other one for the pre-amplifier).

This active antenna has been compared with a 1.5 m whip antenna, connected directly to the receiver, on a DCF77 reception. This comparison was done on the signal to noise ratio (measured by Multipsk). The difference is equal to 20 dB in favor of the active antenna. So the DCF77 time signal can be decoded by Clock with the active antenna but not with the whip antenna.

Hint: the input level must be decreased by the Windows mixer, so as to avoid to overload the signal, and to get a good decoding.

The following picture shows how, externally, this active antenna looks like, with the PC and the receiver, the Clock program being decoding the France-Inter time frames. The active antenna is installed on a rotating support. The variable capacitor (C6), too big, has not been placed inside the metallic box. It is connected to the LW/MW switch with a small coaxial cable.

The receiver audio signal (at constant signal) is transmitted to the « Microphone » input of the PC, the level being adjusted by the Windows mixer.
Of course, this active antenna must be installed outside or, at a minimum, inside but stuck against the glass (except in France for "France-Inter" which seems to be received in any condition, even facing the wall…).

Note about the failure on the use of OA (Operational Amplifiers)
The author tried to replace the BF961 by an OA (TL081) in non-inverting amplifier, and, afterwards, to replace the 2N2222 by an OA in voltage follower. In all cases, the OA generates a self-oscillation.

4.2 Other diagrams

It can also be used a ready to use pre-amplifier, as the one proposed at this address:
https://www.radioelec.com/preamplificateurantennerecepteurpogo-xml-354_384-1303.html
Below is shown the active antenna diagram, integrating this pre-amplifier.

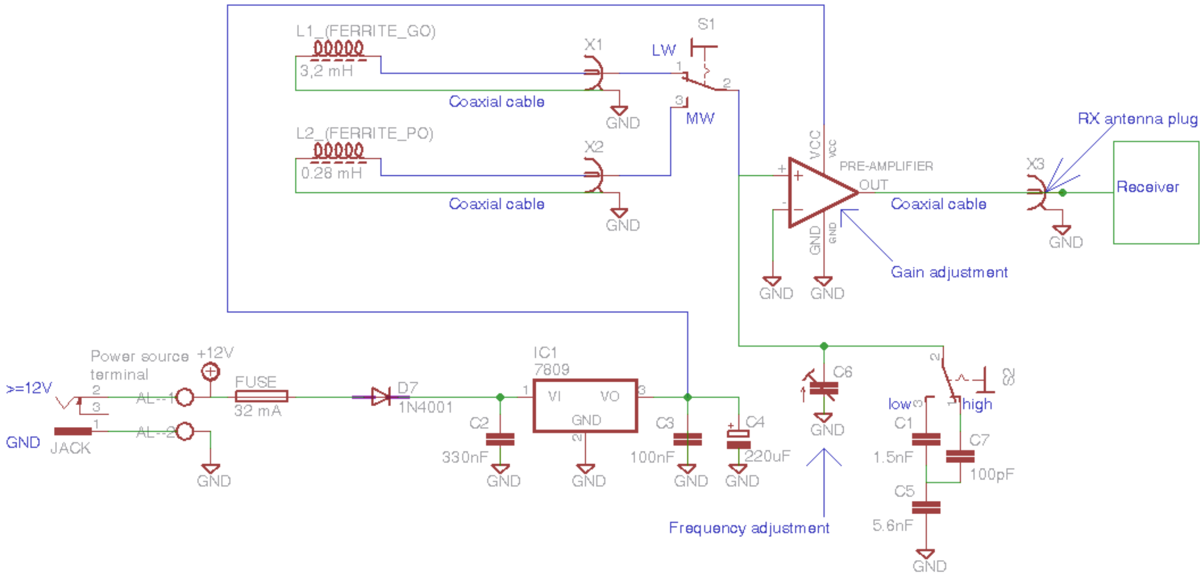

Figure 5

The input impedance of this pre-amplifier does not seem very important, which limits the tuned circuit quality factor Q to 27, at 137 kHz for the above diagram, the bandwidth at -3 dB being of 5 kHz, value which remains correct. However, the voltage gain is important: up to 200 times (!).

The 9 V stabilized supply from a minimum 12 V voltage is standard.
Note that if the user disposes of an exterior stabilized voltage between 5 and 12 V, the C2 and IC1 components can be omitted.

Note that the following diagram was previously tested. Varicap diodes were used instead of a variable capacitor (C6) with fixed capacitors in parallel (C1,C5 and C7).

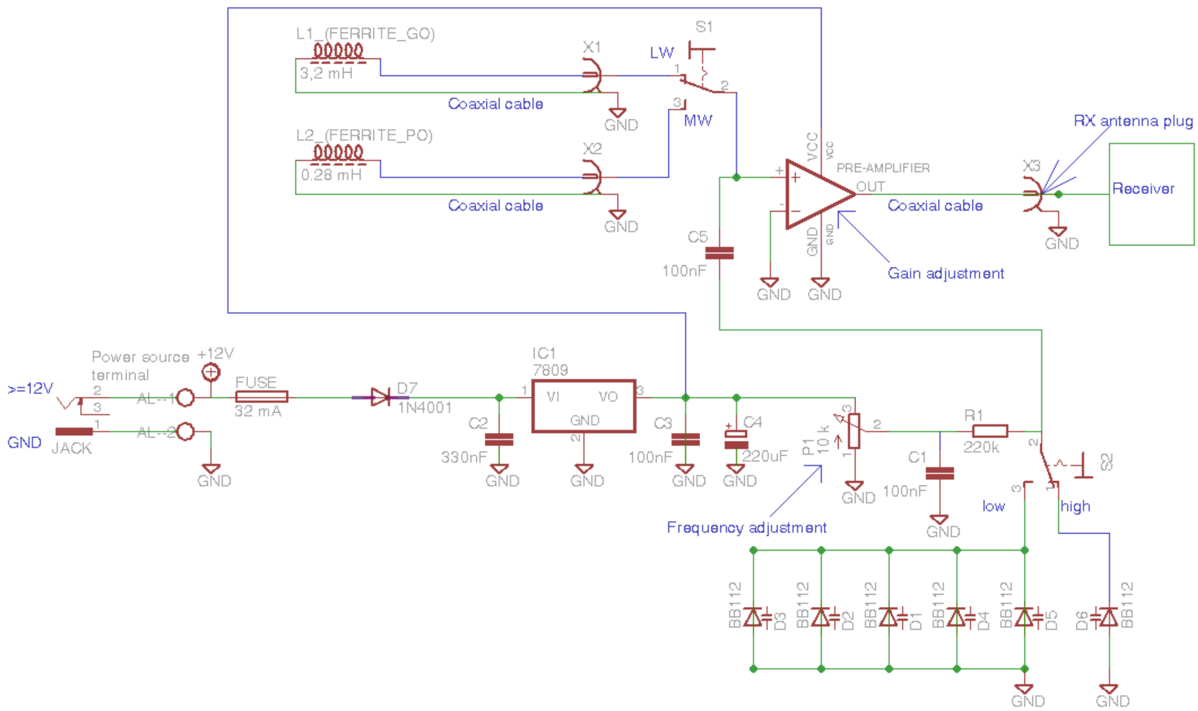

Figure 8

These diodes permit:

- a frequency remote control,
- to have any frequencies adjustment range, by fixing the number of Varicap diodes in parallel.

The disadvantage of Varicap diodes is that the tuned circuit is more damped, compared to a variable capacitor (CV): Q=14 at 137 kHz for Varicap diodes against 27 for the CV.

5. Conclusion

In town, an active antenna based on a ferrite is well matched to receive and decode LW/MW transmissions. An air loop antenna might do as well as (and even better than) a ferrite, but the author did not test this possibility.
In the countryside (no home-made noise), a simple vertical whip antenna is perhaps enough, but it has not been checked.

This antenna must be connected to an electronic permitting :

- the amplification of the signal,
- the matching of the elevated tuned circuit impedance to the 50 Ω receiver input.

6. References

[1] « 2200-meter band » by Wikipedia
https://en.wikipedia.org/wiki/2200-meter_band

[2] « Loop antenna » by Wikipedia
https://en.wikipedia.org/wiki/Loop_antenna

[3] « Antenne ferrite » by Olga Novel and Michel Terrier:
http://www.michelterrier.fr/radiocol/detail2009/antenne-ferrite.htm