CONFERENCE PAPER

STAKELESS FENCING FOR MOUNTAIN PASTURES[1]

M.O. Monod, P. Faure, L. Moiroux, P. Rameau

This paper describes the development and testing of an effective livestock fence which does not use stakes or barbed wire, based on an electromagnetic coupling between a wire unrolled on the ground around the cattle and electronic devices carried by collared animals. The wire, which is insulated, can be on ground, vegetation, or even buried. It is insensitive to the presence of water and is no danger to humans. More than 800 days of experiment on 150 cattle of different breeds were carried out in France in mountain pastures between 1999 and 2003. This system could allow for environmental renovation of wild areas and help to more precise management of grazing in protected zones by bringing more flexibility in fencing.

Keywords: grazing management, virtual fence, herd control, electronic collars.

1. Introduction

Fencing remains a substantial expense today in production agriculture but its costs extend far beyond economics and include social and environmental concerns (Anderson 2007). Today environmental expectations defined by European policies have to be taken into account (Bignal 1998), (Kleijn et al. 2003). These ecological aims imply a precise control of grazing to maintain biodiversity through improved biotope management (Adler *et al*. 2001), to limit soil erosion due to over-grazing (Evans 1997), to conserve the countryside and to redevelop wild areas and waste lands abandoned by agriculture (Sutherland 2002). These new constraints demand greater flexibility in herds management: grazing areas must be changed with the season in line with protected areas, the density of animals has to be reduced in the areas of greatest soil erosion (Van den Bos *et al*. 1990), while stock must be re-introduced into those areas which are no longer in agricultural use (Pykälä 2003).

Conventional fences are static tools that are very effective in controlling animal ingress or egress but fail to offer managers the flexibility they need to optimize the physiological requirements of the vegetation with the nutritional needs of foraging animals. Their installation is costly and time and labor consuming. Moreover, erecting fences may be prohibited in protected zones or difficult in rocky terrain or scrubland.

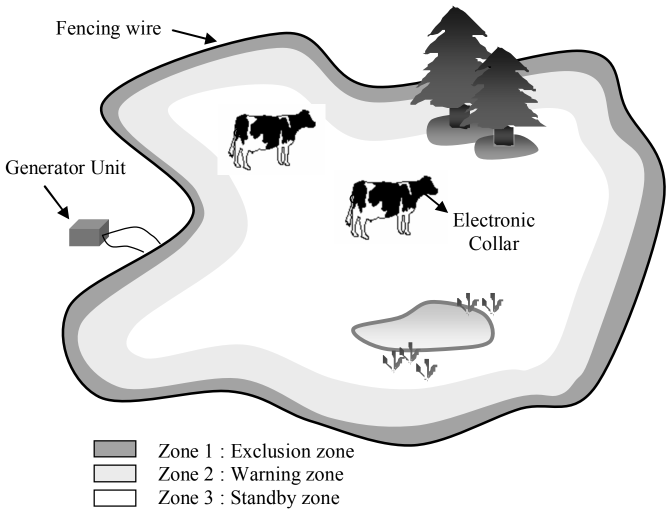
Virtual fencing offers the possibility of controlling herd by placing a visually unseen boundary around animals. Since the first virtual control device described by Fay (Fay *et al*. 1989) in 1989, the most part of developed systems were intended to animal behaviour research (Schlecht *et al*. 2004). The goal is to show that virtual fencing can become a powerful tool for sustainable management of mountain pastures.

1. This paper was originally presented at the 4th European Conference on Precision Livestock Farming and is reprinted by kind permission of the Conference Organisers. It is extracted from the Proceedings: Lokhorst, C and Groot Koerkamp, P.W.G. (eds) (2009) *Precision Livestock Farming '09*. Wageningen Academic Publishers, Wageningen, NL, ISBN 978-90-8686-112-5. The *Journal* will carry a review of this and its sister volume (Precision Agriculture '09) in a future issue.

2. Principle of the virtual fence

The virtual fence presented in this paper was developed with the help of stockbreeders, rangeland managers and specialists in animal behaviour (Dobremez *et al*. 2000), (Freger 1998). The main criteria which were highlighted in designing a new fencing device are that it should be easy to manipulate in erecting and taking down, usable on any kind of land (sloping, rocky, scrubland or dry land), cover large areas, have long autonomy and be discreet in the landscape.

Figure 1. Principle of the virtual fence



The principle is the following: an insulated wire is unwound all around the animals and a generator unit supplies the wire with a low intensity encoded current in order to create an electromagnetic field around the wire. Electronic collars powered by batteries are carried by the animals and prevent them from crossing the wire. The collar detects the presence of the electromagnetic field, informs the animal with an audio signal and, if need be, applies an electric stimulus to the animal's neck.

When flowing, the current produces an electromagnetic field around the wire. Three zones can be defined, as shown in Figure1, which are delimited by the increasing intensity of the electromagnetic field: (i) the standby zone where the collar remains idle, (ii) the warning zone where the animal approaches the limit and can hear the warning signal and finally, close to the wire, (iii) the exclusion zone where the animal receives an electrical stimulus.

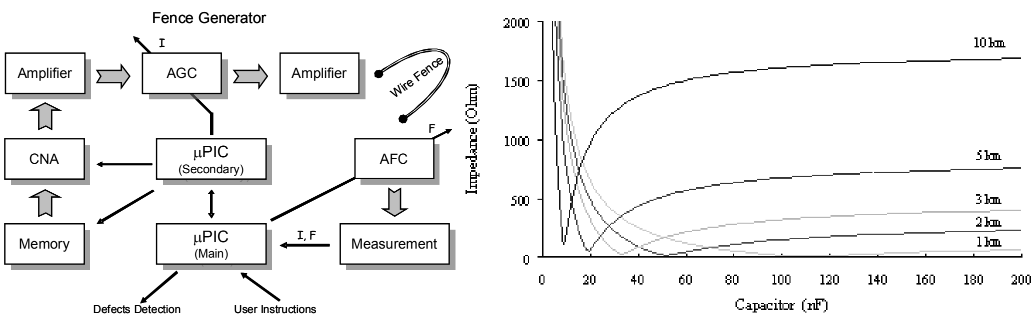
Unlike an electric fence, it is not the sight of the wire (which can be obscured by vegetation) but an audible signal which warns the animal of the presence of the fence. After a training period of approximately half a day, the animals adapt easily. Because they received several electrical stimuli during the training interval, then after this period only the audio signal is necessary to prevent them from crossing the wire.

3. The generator unit and the wire

The major role of the generator unit is to supply the wire with the current needed to create the required magnetic field. So current has to be automatically adjusted in magnitude to compensate for the possible variations of the wire impedance. In addition, to guarantee the limits of the boundaries of the different three zones, the magnetic field and therefore the current must be kept constant. Another requirement is to minimize the energy supply of the device, in order to provide an adequate running time during summer grasslands.

The fence, which is considered as a loop, has a length that can vary from about a hundred metres up to several kilometres. If the current flowing in the loop has frequency components, the impedance of the wire becomes not purely resistive. From an electrical point of view, the wire has to be considered as an inductance L in series with a resistance R. The R value varies in relation to the length and to the electrical characteristics of the conductor (material, section) and to the temperature. The inductance L varies with the length too but also with the geometry of the wire contour. The inductive behaviour of the fencing wire creates a variable reactive load on the generator unit. This load increases with the radius of the fence. The whole impedance also depends on the frequency. The generator unit must minimize the impedance Z until the load will become purely resistive.

Figure 2. (a) Schematic diagram of the Generator Unit.(b). Variation of the impedance of the wire as a function of the capacitance tuning, considering different lengths of the wire.



(a) (b)

In order to achieve this goal, a set of capacitances is automatically selected by a micro-controller which looks for the resonance when the wire is connected (Figure 2(b)). The tuning operation is carried out when first installing the fence but also at regular time intervals in order to correct possible changes in the impedance induced by a new arrangement of the wire (e.g. changes made by the breeder in the grazing perimeter, without switching off the generator unit).

A schematic representation of the generator unit which includes two micro -controllers is shown in Figure 2(a). The main one is the supervisor. It achieves the capacitance tuning to minimize the fence impedance, controls the secondary micro-controller and runs a permanent operation diagnosis. The secondary micro-controller adjusts the current in the wire and keeps it constant. It also controls the memory where the synthesized signal is stored in order to encode the current flowing in the fence in a specific way. This coding reduces external disturbances and makes possible the electronic collars to identify the fence. A safety procedure warns the user of a break in the wire or a malfunctioning in the tuning procedure (e.g. wire too long or too short). The generator unit is battery or solar powered (Figure 4-a).

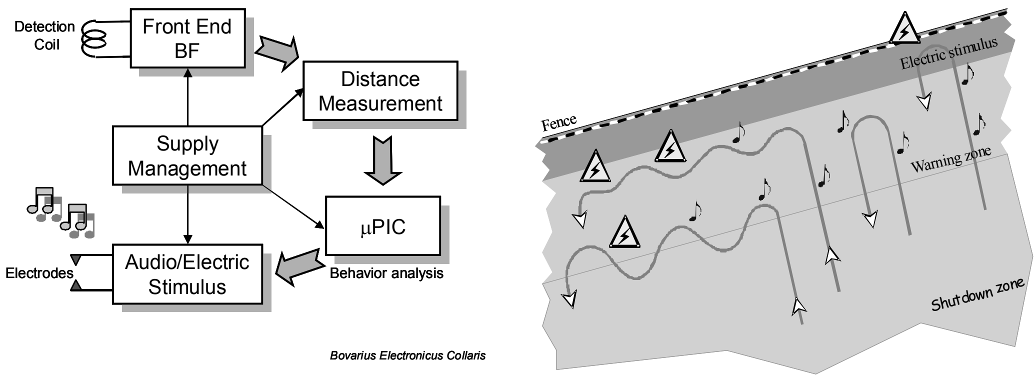
4. The electronic collars

The magnetic field that is emitted by the fencing wire is intercepted by the detection device in the collar on the animal's neck. As it is impossible to get large detection surfaces in the collar, a solenoid is used in order to increase the flux. Such a coil has numerous turns and a magnetic core with a high permeability. Given the weak coupling between the fence and the collar, the detection device must be tuned to the frequency of the signal emitted in the fence.

One of the most important constraints for the electronic collar is energy management. Indeed, in mountain areas the herds pasture for the summer for 6 to 8 months. The collar, which is battery supplied, must have the same running time.

Careful management of the energy consumption of the collar is therefore essential. It is for this reason that a standby zone is defined, where the only first detection module functions. By carrying out an accurate measurement of the voltage induced in the collar, it is possible to calculate the distance between the animal and the wire and thus define several zones. A few metres before the wire the animal comes into the warning zone. The collar wakes up and begins to control the animal's behaviour by sending an audio warning signal. If the animal goes further it enters the exclusion zone. These two boundaries are adjustable, the typical limit of the action zone being 1m and that of the warning zone being 3m from the fence. The zones management program in the collar guarantees the same detection distance for all the

Figure 3. (a) Schematic diagram of the electronic collar. (b). The different scenarios describing animal's behaviour facing with the virtual fence and action to be taken (audio signal or electric stimulus)



(a) (b)

animals to within about 10cm on average, which corresponds to a standard deviation of 4cm.

The collar contains a specific algorithm which needed numerous observations of animal behaviour during both night-time and daytime when animals were faced with the fence. Following these observations several scenarios were identified and have been translated into an algorithmic form (Figure 3(b)). So, an animal which goes into the warning zone for the first time will not undergo the same treatment as one which has been there for a long time. The program builds a history of the animal’s behaviour, compares it with the typical recorded scenarios and then chooses the appropriate action to be taken.

The schematic diagram of the electronic collar shown in Figure 3(a) comprises a receiver which amplifies and filters the weak signal emitted by the fence. When the level of this signal is strong enough the micro-controller wakes up. A first analysis is carried out in order to recognize the specific fence signal. Then the animal-to-wire distance is calculated to identify the zone the animal is in. According to the animal’s behaviour, stimulus can be activated either in the warning mode (audio signal) or in the stimulation mode (electric stimulus).

Figure 4. (a) Generator and fencing unit. (b) Electronic collar

(a) (b)

The collar is equipped with flexible electrodes bent inside of each part of the strap, so that the electric stimulus is applied on each side of the animal's neck (see Figure 4-b and Figure 5-a). The intensity of the optimal electric stimulus was selected after carrying out numerous electric measurements on cattle. The energy delivered to the animal is similar to that of an electric fence. It complies with IEC-479-1 safety standards. In particular, the charge time of the transformer which transmits the stimulus is long enough to save the animal from receiving too-frequent impulses. In the case of the animal being trapped in the exclusion zone, an additional security device will stop the electric impulses. The collar is powered by four 1.5V AAA batteries.

5. Experiments and results

First measurements and experiments were carried out at Cemagref (farm of Montoldre, Allier). Then, numerous experiments were carried out in French natural reserves on more than 145 animals comprising breeds of dairy and beef cattle for more than 800 days between 1998 and 2003 (see Table I).

The successive technological evolutions of the system (three versions were developed between 1998 and 2001) do not allow us to present the results in a detailed form, which were very different according to the versions. The results presented in this paper only sum up the number of animals and number of days of experiments carried out in each situation.

We observed that a training period of half a day was necessary in order to familiarize cattle with the electromagnetic fence. Training was accomplished by establishing a short loop (20m diameter) inside a conventional fence and confining the animals to this area. After one or two electric stimuli, the animals seem to know where the exclusion zone is. In some cases we noted that several animals were able to learn without any electric stimulus, but only by observing the behaviour of their companions.

In natural reserves, the fencing wire was unwound on the vegetation and consequently was not visible everywhere by the animals (see Figure 5-b). In this situation, we observed that animals test the presence of the wire with the help of the audio signal but never enter the exclusion zone.

In regions where wild fauna is numerous, the wire has been buried in order to avoid being broken by free animals such as wild boars, stags or deer.

A six months experiment led in a protected zone of the French reserve Parc du Livradois-Forez (France) with 12 bovines showed that only one animal lost its collar in scrub. Situated in a mountainous region the fence was twice struck by lightning. A security system was added later.

Table 1. Summary of stakeless fencing experiments on bovines

Location	**Period**	**Breed**	**Number of Animals**	**Number of Days**
Cemagref farm (Montoldre)	1998-2001	Charolaise	75	180
Parc des Volcans d'Auvergne	1999	Prime-Holstein	10	60
Parc des Cévennes	2000-2001	Salers-Limousine	30	40
Parc du Ballon des Vosges	2002	Vosgienne	12	220
Parc du Livradois-Forez	2003	Aubrac	12	180

6. Conclusion

Virtual fences incorporate many of the advantages of herding by using electronic technology to replace manual labour without drawbacks encountered with conventional fencing, its being static and difficult to move. The virtual fence we present here is based on the electromagnetic coupling

Figure 5. (a) Collared animals (Charolaise breed). (b) The stakeless fence in mountain pastures (Puy de Dome, France). The fencing wire and the boundary between the grazed and the no-grazed area of the pasture can be seen on the left side of the image

(a) (b)

between a wire unwound on the ground (the fence) and electronic collars carried by animals. This system is commercially available since 2008. It can be expected that virtual fences using GPS (Global Positioning System) will appear in few years, when the restrictive problems of energy are solved. The numerous experiments which have been carried out during this project show this new fencing device could offer breeders and rangeland manager new possibilities in grazing management to respond to environmental constraints required by European directive. Biotopes can thus be protected and waste lands can be returned to pasture in natural areas where traditional fencing is prohibited or impossible to erect.

Acknowledgments

The authors gratefully acknowledge the French manufacturers A.R.B, C.R.E.B, Chapron-Leménager, LACME and ANVAR Auvergne and the French natural reserve Parc National des Cévennes who supported this work.

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