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ULTRA LOW FREQUENCY CONTACTLESS SMART CARDS

D. Ciudad[*]— L. Pérez[**]— P. Sánchez[*]— M. C. Sánchez[**] — E. López[**]— C. Aroca[*]

A new contactless system that can work at ultralow frequencies (<100kHz, 2kHz used) has been developed. At this frequencies the screening problems of the current technologies are avoided. It is characterized by the use of a tunable magnetic sensor; concretely, a fluxgate with a double demodulation technique, as detection module. The main difference with the commercial systems used at present is that it is based on the detection of the magnetic field produced by the card, not on an inductive coupling. Due to the incorporation of a magnetic core, the card does not need a resonant circuit.

Keywords: contactless, smart card, RFID, double demodulation, fluxgate, tunable sensor, magnetic core.

1 INTRODUCTION

Contactless smart card systems are widely used in automatic control access, ticketing, etc. These systems are based on an inductive coupling between an excitation coil, that provides an alternating magnetic field, and a set of coils integrated in the card. Capacitors are used to drive the systems at their resonance frequency. The system send information to the card by modulating the magnetic field and the card send information by changing its impedance by using an integrated circuit.

Nowadays there are three different technologies. One based on low frequency (LF - 125 kHz), used in animal tracking and security door access and other two technologies based on high frequency (HF - 13.56 Hz): ISO 14443 ("proximity cards" for contactless ticketing) and ISO 15693 ("vicinity cards" for smart labels). A good discussion about all them can be found in [1].

These systems have problems due to screening effects that can be avoided by reducing the frequency. Nevertheless, the frequency cannot be reduced below 100 kHz because of two reasons:

1. The EMF change in the excitation system when the card is sending information decreases with the square of the frequency.
2. If the frequency is reduced to the half, a capacitor with a capacitance four times higher must be used in order to work at the resonance frequency.

In this work, we present a new contactless card system capable of working at ultra low excitation frequency (<100 kHz). Driving frequencies as low as 1.9kHz have been used.

2 DESCRIPTION OF THE SYSTEM

The method described in this paper is not based on an inductive coupling but in the measurement of changes in the magnetization of a magnetic core integrated in the card with a winding around it. An external alternating magnetic field induces an EMF in it. By shorcircuiting the winding, the magnetic field produced by the induced current is high enough to produce a change in the magnetization of the core, due to the very small distance between core and winding. The change of magnetization when the windings are short-circuited can be detected by a tunable magnetic sensor and, in this way, the card can send information.

This system has not the two previously referred problems of the systems currently used: the magnetic field produced by the coils that forms the card decreases linearly, not squarely, with the frequency and the coils are set close to the magnetic core and, therefore, to work in the resonance is not necessary.

As it is shown in Fig. 1, the system has three different modules: excitation, reception and card.

2.1 EXCITATION

The system used for the excitation of the card has to produce an alternating magnetic field, except in a region in which the magnetic field should be negligible to place there the reception system avoiding its saturation. A pair of Helmholtz coils connected in opposition and driven by a 1.9 kHz current has been used. The detection system is placed in the middle point of the two coils, where the field is almost zero. The expression of the axial field created by the system is:

$$H(z) = \frac{1}{2}R^2 I\left(\frac{1}{\left(z^2+R^2\right)^{3/2}} - \frac{1}{\left((z+R)^2+R^2\right)^{3/2}}\right)$$

where R is the radius of the Helmholtz coils, z the distance between the point to the center of the nearest coil (with positive values from the coil to out of them) and I is the current intensity in the coils

2.2 CARD

The card is formed by a magnetic core rounded by a winding and it should have a system capable of short-circuiting the winding and keeping information (*eg* an integrated circuit IC).

[*] ISOM-ETSI Telecomunicación, Universidad Politécnica de Madrid (UPM), c/ Universitaria, s/n, 28040 Madrid, SPAIN, E-mail: dciudad@fis.upm.es
[**] Dpt. Fisica de Materiales, Facultad de Fisica, Universidad Complutense de Madrid. Ciudad Universitaria s/n, 28040 Madrid, Spain

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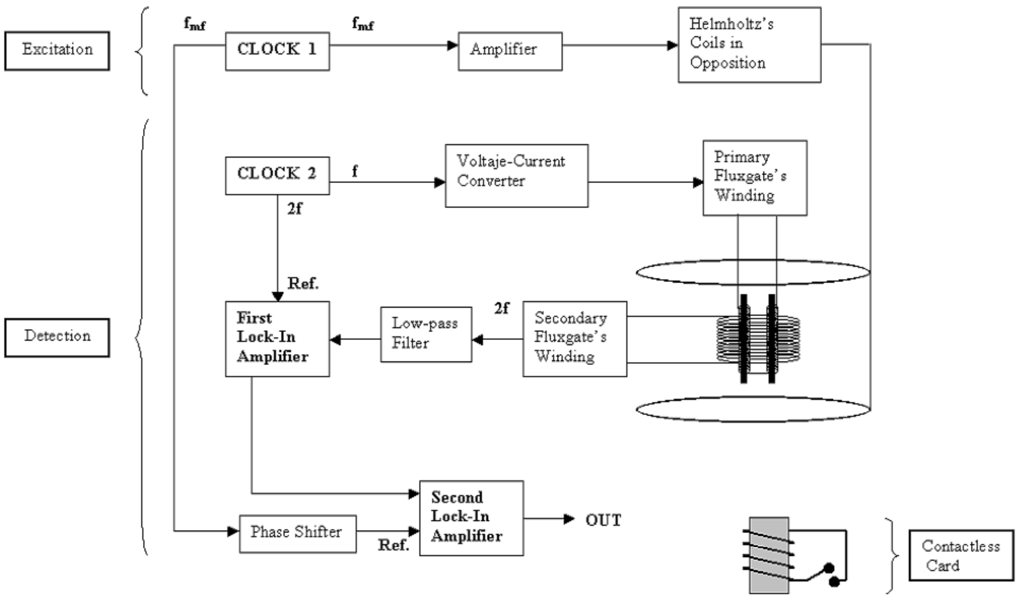

Fig. 1. Block diagram of the system

The change of the magnetization of the magnetic core when the winding is closed can be written as:

$$\Delta M = \chi_m H_{wc} = \chi_m nI = -\chi_m n \frac{1}{R_c}\frac{d\phi_m}{dt}$$

where H_{wc} is the field produced by the winding, n the number of coils per unit of length, I the current at the card's winding, R_c the resistance of the winding and Φ_m the magnetic flux through it. The amplitude of the magnetic field, that can be considered sinusoidal, is:

$$B_0 = \frac{R^2}{2} I_0 \mu \left(\frac{1}{(z^2+R^2)^{3/2}} - \frac{1}{((z+R)^2+R^2)^{3/2}} \right)$$

Considering that the longitudinal axis of the card is in the axis of the Helmholtz coils and that the section of each coil is S, in a first approximation we can write:

$$\Delta M = -\chi_m \frac{nS\omega B_0}{R_c}\cos(\omega t)$$

When the winding is short-circuited the change in the dipolar moment with open or closed winding are (l is the length of the card):

$$|\Delta m| = \chi_m \frac{nS^2 l\omega B_0}{R_c}\cos(\omega t)$$

A card with the shape and dimensions of a credit card has been fabricated using two printed circuit boards with the tracks of the winding in the outer part and a soft magnetic thin film in the inner part. To fabricate the card both boards have been joined and the tracks have been

2.3 RECEPTION.

To detect the magnetic signal from the card, a tunable sensor, placed in the region in which the alternating field is negligible, should be used. In this work we have used a fluxgate with a double demodulation similar to the one reported by Aroca and collaborators [3].

Supposing that the magnetic core behaves like a magnetic dipole, the change of magnetic field that should be detected by the fluxgate when the card is placed at a distance *r* from it is:

$$|\Delta B_{card}| = \frac{\mu_0}{2\pi}\frac{\Delta m}{r^3} = \chi_m \frac{\mu_0}{2\pi}\frac{nS^2 l\omega B_0}{R_c}\cos(\omega t)\frac{1}{r^3}$$

2.4 ELECTRONICS

All the signals are obtained from a Programmable Integrated Circuit (PIC 16F84A) using a Digital-to-Analog Converter (DAC 0808).

The fluxgate is driven by a sinusoidal current signal of 12kHz (*f*) supplied by the PIC by using a current-voltage converter. The amplitude of the second harmonic induced in the secondary winding of the fluxgate is proportional to the applied magnetic field. A first demodulation made with a lock-in amplifier (Figure 2), using 2*f* as the reference frequency, gives the second harmonic rectified.

A second demodulation is made to detect a field with the same frequency that the alternating magnetic field (f_{mf}) produced by the excitation system. This allows the measurement of the variation of the field produced by the magnetization of the card.

The output of the fluxgate is filtered before introducing it in the first lock-in by using a low pass active The PIC is programmed to give the proper phase between the two signals in the first lock-in directly. To control the phase before the second lock-in amplifier a phase shifter is introduced. In the first lock-in the components used are R_1 = R_2 = R_3 = R_4 = R_5 = 20kΩ,

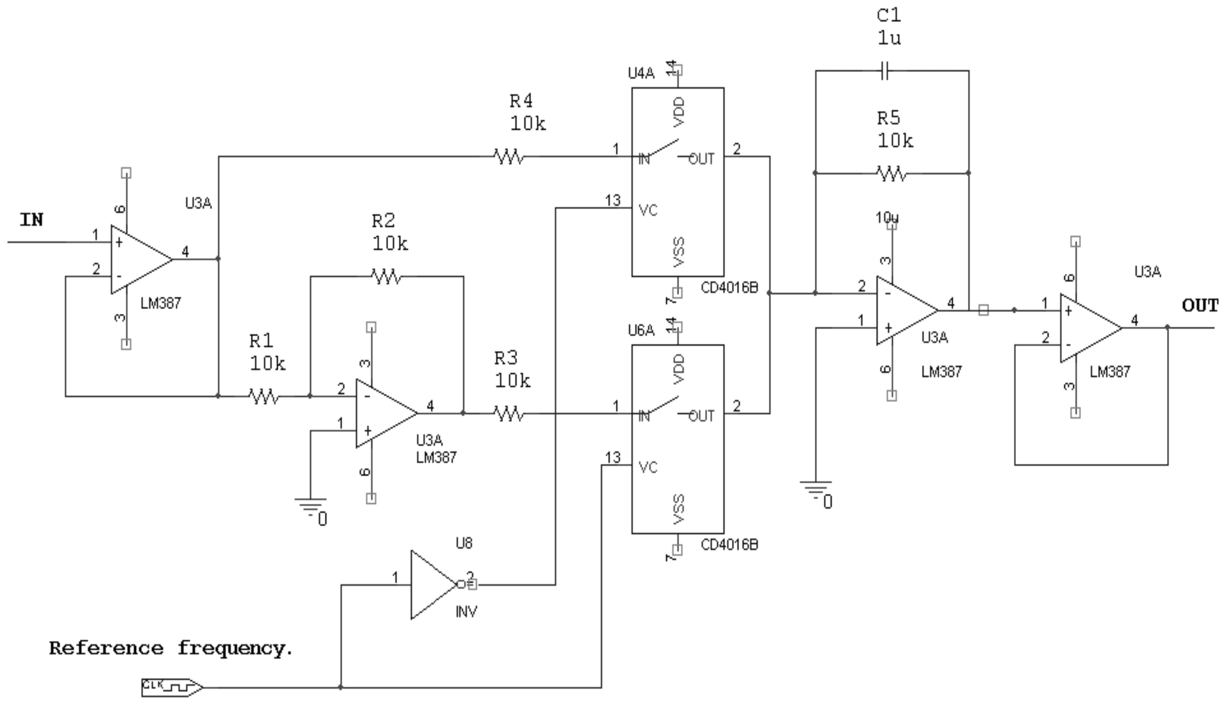

Fig. 2. Lock-in amplifier

$R_5 = 500\ \mathrm{k}\Omega$, $C_1 = 1$ nF. In the second lock-in amplifier: $R_1 = R_2 = R_3 = R_4 = 20\mathrm{k}\Omega$, $R_5 = 500\ \mathrm{k}\Omega$, $C_1 = 580$ nF.

3 EXPERIMENTAL RESULTS

Before testing the system, the magnetic field produced by the excitation Helmholtz coils has been measured with a Hall probe (Figure 3) at different distances from the center of the nearest of the Helmoltz coil (d):

$$d = r - \frac{R}{2}$$

In order to study the screening effects, measurements has been carried out introducing the card in aluminium coverings with thicknesses ranging from 13 to 200 microns. The dependence of the EMF on the Al thickness just at the center of the coil ($d = 0$) is shown in Fig. 4, where a linear screening can be shown. The behaviour of the EMF with the distance d is similar for all the Al thicknesses (Figure 5). Although the field used is very low, close to the earth magnetic field, a non negligable EMF is induced even at a distance of 15 cm from the excitation system and using a 0.1 mm aluminium covering.

Figure 6 shows the change of the signal obtained from the fluxgate after doing the double in phase demodulation when short-circuiting the winding of the card. Despite the low magnetic field used for the excitation, the card can send information even if it is introduced in a conductive envelope and this information can be detected at 14 cm from the excitation system. This distance could be larger if noise is eliminated by integrating a longer time at the second lock-in, however, it produces a worse response time.

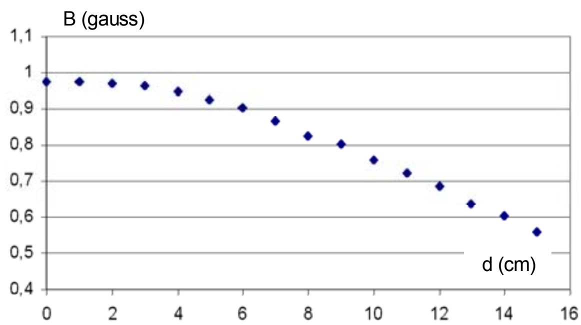

Fig. 3. Applied magnetic field versus distance.

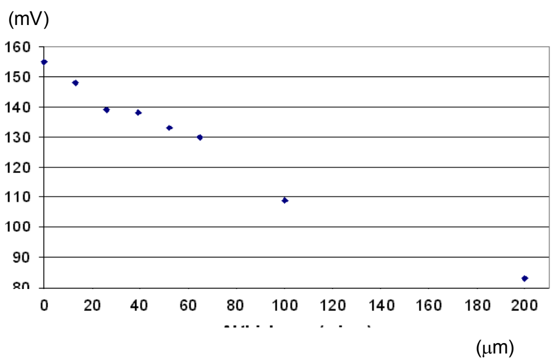

Fig. 4. EMF versus Al thickness

4 CONCLUSIONS

To sum up, a new contactless system for smart cards applications able to work at frequencies below 100 kHz has been developed. The system is based on the measurement of the changes of magnetization in a magnetic core.

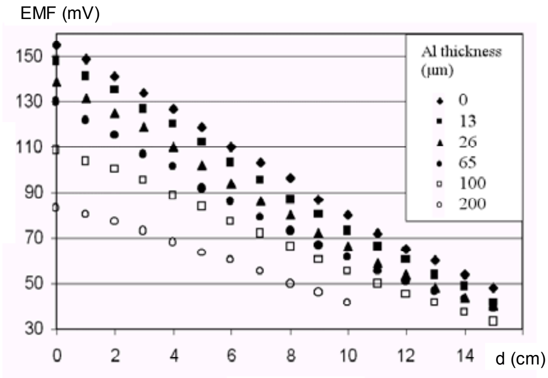

Fig. 5. Fluxgate signal versus distance

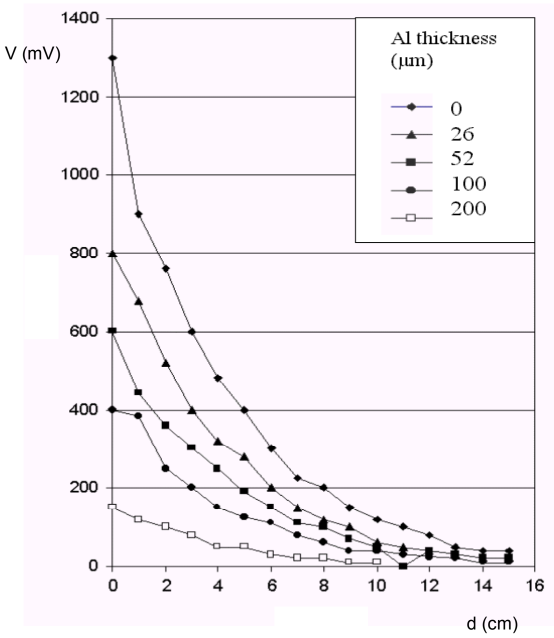

Fig. 6. Fluxgate signal versus distance

The main advantage of this system is that it avoids the problems related to the magnetic screening that the currently used systems exhibit. As a matter of fact, in spite of the low magnetic field used for the excitation, the card has been detected through envelopes of aluminium with different thicknesses up to 0.2 mm at even 14 cm from the nearest of the Helmholtz coils and 25 cm from the fluxgate.

The viability of the system has been successfully tested. For further work, an integrated circuit should be integrated in the card to keep the information and to short-circuit the winding for sending information. If the card is short-circuited at a fixed frequency, a third demodulation could be done and the sensitivity of the system -and so, the maximun distance in wich the card is detectable- for a determined magnetic field should improve.

In addition to the previous advantages, all the used technologies (PCB and electrodeposition) are usually used in industrial fabrication processes.

Acknowledgements

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