Design and Optimization of a Multi-Induction-Loop Access Control System

Abstract – In access control systems the key concern is to obtain signals only in a restricted area such that the sender coils do not influence each other and that access is given to persons located in the area of interest only, avoiding access of unauthorized persons given by remote authorized persons. Hence the sender coils should produce a magnetic field, which is not smaller than a minimum required field, only in a limited area.

In this paper the shape of the sender coils as well as the materials in the system are optimized such the desired quality figure of the magnetic field is met.

Keywords – EM coupling, Shielding, Numerical Modeling in EMC, EMC in Automation Systems, Measurements and Instrumentation

I. INTRODUCTION

Induction based access control systems operate at frequencies at which radiation can be neglected. A sender coil produces a time varying magnetic field, which induces a voltage in a conducting loop shrink-wrapped into a chip card. The main advantage of such a system over the conventional magnetic-strip based approaches is the comfort for the user (for instance, the induction loop chip card needs not to be drawn out of a waistcoat pocket).

The sender loop has to produce a minimal field strength in a certain area, such that the chip card can withdraw energy from the field and store it (in a capacitor) until enough energy is available to wake up the card’s electronics. Then the card starts "sending" a unique code by means of switching the load on the receiver coil between high and low impedance and thus modulating the field strength. This modulation can be detected in the sender coil (very small signal-to-carrier ratio (SCR)). The card utilizes the high impedance state during the modulation to acquire energy from the field to maintain the power supply on the card.

The area in which the field is above a certain value has to be well defined such that an authorized person, remote from the sender loop, does not give access to an unauthorized one, standing in front of the gates.

Things turn out to be more complicated in multi-induction-loop access systems, where several sender loops are lined up to give access parallel to a number of persons.

Fig. 1 shows such a multi-induction-loop access control system. Outside the region \( \Omega \), the field has to be below the required field, above which the chip card starts sending, to limit access only to persons located inside \( \Omega \).

Fig. 2 shows a typical induction loop with the access gate. The field on the opposite side of the loop can be reduced by inserting a shield of conducting material where eddy currents are induced producing a magnetic field, which acts in opposite direction of the inducing field. Of course the frequency of the exciting field has to be sufficiently large to produce significant eddy currents in the shield.

II. NUMERICAL SIMULATIONS

To simulate the field problem numerically the finite element method has been applied. Isoparametric hexahedral nodal finite elements ([1],[2]) with twenty nodes and quadratic shape functions are applied to model the geometry of the problem (Fig. 3). The plane of symmetry \( x=0.0 \) m of the entire region has been exploited to reduce the computation and modeling effort of the problem. The computation has been carried out by applying the \( \vec{T}, \Phi - \Phi \) formulation ([3]). To simulate the eddy
currents in the conducting regions the reduced current vector potential $\vec{T}$ is used, whereas the reduced magnetic scalar potential $\Phi$ is employed throughout the problem region. The scalar potential $\Phi$ is represented by means of nodal elements. The vector potential $\vec{T}$ is approximated by means of edge elements. Experience has shown that it is more favorable not to gauge these vector potentials and to solve the arising singular systems by iterative methods like the Incomplete Cholesky Conjugate Gradient technique leading to robust solutions. The numerical stability of these formulation is perfect, provided the consistency of the right hand side of the equations is ensured. The sender coil has been modeled as current filaments efficiently.

For the comparison of the shielding effect, the shield was a ferrite with a conductivity of $\sigma=1$ S/m, for the first case and aluminum with a conductivity of $\sigma=3.5\times10^7$ S/m, in the second case. The pillars, on which the coil is mounted, are made of aluminum and have to be considered in the model.

In Fig. 5 the maximum value of the magnetic flux density is shown for the ferrite shielding case, whereas the maximum value of the magnetic flux density for the aluminum shielding case is shown in Fig. 4.

The magnetic flux density in the shield of Fig. 5 differs significantly from the one in Fig. 4 due to the eddy currents induced into the shielding plate.

In Fig. 6 and Fig. 7 the maximum modulus of the magnetic flux density can be seen on two planes parallel to the shield in a distance of 0.4 m from the sender-receiver coil. Although the field is smaller behind the shield in both cases, the shielding effect of ferrite is insufficient.

In Fig. 8 the magnetic flux density can be seen on a line through the center of the coil normal to the coil plane.
III. OPTIMIZATION OF THE DEVICE

For the optimization of the sender coil, which also acts as a receiver, several tasks have to be considered:

- the magnetic flux density has to be greater than a certain value only in a restricted area
- the signal to carrier ratio should be improved without increasing cost of production
- the material and shape of the shield should be optimized with respect to effectiveness and cost

To meet the above, partially conflicting, requirements a mathematical optimization is performed. Since the time requirement of the optimization is not crucial in this particular case and because of its ease of use a stochastic method, namely Particle Swarm Optimization (PSO) [4] is applied.

The results of this optimization will be reported in the full paper.

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References


