LABORATOIRE D'ELECTRONIQUE
ANTENNES ET TELECOMMUNICATIONS

Sophia Antipolis, le 30 Janvier 2015

Proposition de sujet de thèse dans la cadre du LABEX.
Equipes impliquées CMA/LEAT- INRIA -TIRO MATOS
Axe : esanté.

SMART-RATS

Small Animals RFID Integrated Antenna Tracking System

1. Project Relevance and Strategic Importance

Animal tracking and behavior analysis has always been an important task in several domains, such as the study of animal migrations, the analysis of the effects of climate changing, wildlife management and farming, and animal health monitoring. It becomes even crucial when it applies to small laboratory animals, which are used for the test and evaluation of the effects of new drugs and vaccines for humans.

Among all the types of animals employed in medical testing, mice are the most commonly used because of their small size, low cost, ease of handling, and fast reproduction rate. Moreover, they are widely considered to be the best model of inherited human disease and share 99% of their genes with humans [1]. According to the statistics reported by the Commission of the European Communities to the Council and the European Parliament, the number of mice used for experimental and other scientific purposes in the European Union (UE) in 2005 amounts to about 6.4 million animals [2]. Moreover, the testing of just one substance alone can involve up to 800 animals and cost over $6 million [3].

Given these numbers, it is straightforward that new technological systems able to improve the testing procedure in terms of comfort of the animals, accuracy of the collected data, or velocity of the process must be sought [4-5]. The use of the Radio Frequency Identification (RFID) technology seems to be the best choice to address this problem, since it overcomes the limitations typical of other existing solutions based on the Global Positioning System (GPS), which cannot be employed indoor, or the use of video recording devices, which can be difficult to use when phenotypically identical animals must be simultaneously localized and tracked [6]. Moreover, the cost of video recording systems restricts their use to a limited numbers of cages and could not be easily extended to a whole animal facility.

In this framework, the present research proposal is aimed at designing an RFID-based antenna system for the tracking and behavior analysis of small animals. In particular, the focus is on the monitoring of laboratory mice used for pharmaceutical tests. More specifically, the animals are implanted with passive RFID tags, while a customized near-field (NF) reader antenna system is used to collect Received Signal Strength Indication (RSSI) data that are used to estimate the animal position.

In this sense, the present proposal takes place in the axis « e-heath » of the LABEX. As a matter of fact, the proposed antenna system will be a valuable support for a more rapid and accurate evaluation of the animal behavior, which will consequently help the decision making process related to the evaluation of new drugs, but also a first and important step in implantable communicating and sensing systems in the human body.

During the development of the proposed study, several aspects of interest for the e-health societal challenge will be addressed. They include the interaction between living subjects and innovative technologies, the development of dedicated numerical modelling, the integration and exploitation of the collected data, the development of intelligent estimation algorithms for the activation of autonomous actions.

2. Scientific and Technological Objectives

The realization of the RFID-based antenna system for the tracking and behavior analysis of small animals provides for the achievement of the following objectives:

- Design of a small passive RFID tag antennas operating in the 900 MHz UHF band suitable to be implanted in laboratory mice and in a second step in human body.
- Design of a multiple antenna reading systems integrated into the animals' cage to activate as well as collect the information provided by the implanted tags.
- Definition of a localization and tracking algorithm based on the data collected through the RFID-based system.
- Study of the effects of the implanted tag on the mouse body temperature.

In order to meet these objectives, several challenging issues need to be solved:

- **Antenna miniaturization**. The size of the implanted tag is basically determined by the antenna dimensions. Consequently, antenna miniaturization is needed for both the accuracy of the measurement and the patient comfort, i.e. animals in a first step and humans in a second one. Analogously, the antennas on the animal cage must be compact to allow the increment of the number of elements of the reading system and the decrease of mutual coupling effects.
- **Efficiency preservation**. Despite the necessary miniaturization, the efficiency of the antennas must be kept to values suitable to guarantee the communication between the implanted tag and the external reading system.
- **Biocompatibility**. In order to prevent rejection the implanted tag must be biocompatible, i.e. it must be constituted or shielded by materials accepted by the living tissues.
- **Multiphysics modelling**. To evaluate the effects of the implant on the mouse health, the joint simulation of both electromagnetic and thermal aspects is needed.
- **Localization accuracy**. A suitable level of localization accuracy is needed to enable tracking and behaviour analysis. This must be obtained despite the limited amount of information collectable by the reader.

The originality of this project lies in the multidisciplinary approach used to design the whole system. As a matter of fact, the proposal addresses aspects coming from different domains, ranging from antenna and electronic circuit design, numerical modelling, data elaboration, up to biocompatibility analysis, and animal testing. In particular, the optimization of each system block will be performed by carefully considering the rest of the system.

Few examples are:

- The electromagnetic design of the implantable antenna will consider the integration to the RFID chip. By avoiding classical 50Ω matching, the antenna impedance will be directly matched to the chip impedance without the need of matching/balun circuits, thus reducing the tag dimensions.
- The materials used in the design of the implantable antenna will be chosen by considering both miniaturization and biocompatibility aspects.
- The reading antenna system will be optimized with the aim of increasing the diversity among the information collected by each element, resulting in less correlated data that will facilitate the localization estimation.

The methodology for the design of the proposed small animals tracking system will be based on the following phases:

1. **Co-design modelling and simulation.**

   Following the "co-design" concept, the modelling of each system component will consider the environment in which it has to operate (e.g., the mouse body and the animals cage) and the integration with the other parts of the system. This will increase the reliability of the numerical simulations and avoid unexpected results during the integration phase. The precise modelling of the system will also allow multiphysic simulations needed for the evaluation of the effects of the implants on the mice bodies. As for the localization and tracking problem, it will be modelled as an inverse problem, in which the estimation of the target position is obtained starting from measurements performed on the environment where the target is located.

2. **Smart optimization.**

   Given the increased complexity of the models based on the co-design concept (i.e. the large number of variables to be optimized), classical optimization techniques based on parametric studies will be probably ineffective. Consequently, the use of nature-inspired stochastic algorithms as Genetic Algorithms or the Particle Swarm Optimizer will be necessary.

3. **Realization, integration and test.**

   The effectiveness of the proposed system will be successively assessed through experimental validations. Towards this end, prototypes of both the different components and the integrated system will be realized and measured. Homogenous phantoms simulating the mice bodies will be realized by properly mixing de-ionized water and diethylene glycol butyl ether (DGBE).

3. Project Consistency

The multidisciplinary of the project requires competences in different domains, such as antenna design, RFID systems, localization algorithms, etc. They can be ensured by the combination of different laboratories having recognized expertise in each domain.

The project and the PhD student will be mainly hosted by the Laboratoire d'Electronique, Antennes et Télécommunications (LEAT) and in particular within the "Conception et Modelisation d'Antennes" (CMA) group. The objective of CMA theme is the study and design of innovative antenna solutions and the development of new methodologies for the integration and miniaturization of the antenna and the associated circuits. This expertise will represent one of the different resources of the project, which will be completed by the specific skills of the other laboratories researchers such as the expertise in numerical modeling of electromagnetics effects in human tissues developed within the INRIA and the strong collaboration with MATOS (Biologic Mechanisms of Bone Tissue Alterations) biology research group of the University Nice-Sophia Antipolis, which will provide the expertise for the animal experimentation part (biocompatibility, on-site evaluation, practical concept design and testing). The people involved in this project will be Stéphane Lantéri from INRIA, NACHOS project-team, Aliou Diallo, Leonardo Lizzi and Philippe Le Thuc from the CMA team at LEAT, and Georges Carle from MATOS, UNS. The student will be recruited by the LEAT. The thesis director will be Philippe Le Thuc and the co-director will be Stéphane Lantéri.

References

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