

Research proposal for the application for a postdoctoral grant  
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# **Design of Implantable Antennas for E-Health Wireless Sensor Networks**

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**Theme:** Health and Sensor Networks

**Incoming Research Unit:** LEAT - CMA

## **Abstract**

*The proposed research program deals with the design of implantable antennas for E-Health Wireless Sensor Networks. In E-Health applications, implanted sensors are used to perform caring activities like constant monitoring of biological parameters or patient identification and localization. Designing implantable antennas forces to face several scientific challenges, like miniaturization with efficiency preservation, awareness of the environment during the synthesis process, biocompatibility, acceptable Specific Absorption Rate, and capability of energy harvesting. The main objective is the design of antennas for sensor nodes that will be implanted and tested into laboratory mice. The proposed project is intended to be carried out at LEAT (Electronics, Antennas and Telecommunications Laboratory) of the University of Nice-Sophia Antipolis, CNRS. The use of implanted sensors for monitoring, identification and localization purposes will improve the development of therapies, the knowledge of biological phenomena and the study of animal and human being behavioral models.*

## I. Introduction

The recent advances in microelectronics and the evolution of low-cost low-power sensor devices have pushed towards the utilization of monitoring Wireless Sensor Networks (WSNs) for new applications in hostile or previously inaccessible environments. In E-Health applications, specific sensors are implanted in or placed on the patients in order to perform caring activities, such as the remote and constant monitoring of biological parameters.

For this kind of applications, it is clear that the antenna plays a significant role in the overall reliability of the network since it must guarantee the communication despite the difficult environment in which it has to operate. In literature, solutions based on different antenna structures can be found. In order to obtain compact dimensions, geometries allowing for the lengthening of the surface currents paths are the most commonly adopted [1]. Similar solutions rely on the use of fractal shapes, which, thanks to their intrinsic space-filling property, represent good candidates for antenna miniaturization [2]. In addition to the selection of the proper antenna geometry, the reduction of the antenna extension is also achieved by means of other techniques like the use of high-permittivity dielectric material [3], the vertical stacking of radiating elements [4], or the addition of shorting pins [5].

In the majority of cases, the experimental validation of the proposed solutions has been limited to *in vitro* investigations by measuring the antenna prototypes inside tissue-equivalents media (phantoms) [1], [5]-[6]. This approach is certainly the easiest and most practical to implement. However, the formulation and the characterization of the materials emulating the electrical properties of the tissue are not straightforward. Moreover, since electrical properties of the live tissues are dependent to changes in temperature, age, and tissue chemistry, *in vitro* testing does not guarantee the proper functioning of the antennas when implanted in the body. Consequently, *in vivo* verification becomes crucial to investigate the effects of live tissue on the performance of implantable antennas. Because of the complex procedures (choice of the animals, pre-surgical preparation, anesthesia, surgical procedure, etc.) needed for testing inside living animals, the number of *in vivo* studies reported in literature is very limited [7].

## II. Research Project

The objective of the present research project is the design of innovative antenna solutions dedicated to the utilization in WSN for E-Health applications. Following the international regulations, the focus will be on antennas operating over the 402-405 MHz Medical Implant Communication Service (MICS) band or over the newly established 401-406 MHz Medical Device Radiocommunications Service (MedRadio) band. However, also the Industrial, Scientific, and Medical (ISM) bands, which have been suggested for implantable medical device biotelemetry in some countries, will be considered.

The design of implantable antennas requires facing several scientific challenges:

- **Miniaturization.** At the frequencies allocated for implanted systems, traditional half-wavelength or quarter-wavelength antennas are useless. Consequently, techniques aimed at reducing the overall occupancy of the antennas are required.
- **Efficiency Preservation.** Despite the necessary miniaturization, the antenna efficiency must be kept to values suitable to guarantee the communication with the external devices.
- **Environment Awareness.** The environment in which the antenna has to operate must be taken into account during the design process. Techniques aimed at reducing the required time and computational resources are needed.

- **Biocompatibility.** In order to prevent rejection of the implant and to preserve patient safety, implantable antenna must be biocompatible. Moreover, since human tissues are conductive, the antenna metallic parts must be isolated in order to avoid undesirable short-circuits.
- **Acceptable SAR.** For the patient safety, the maximum allowable power incident on the implantable antenna must be limited. A generally accepted dosimetric measure is given by the Specific Absorption Rate (SAR), which must comply with the international regulations.
- **Energy Harvesting.** In order to reduce the dimensions of the implantable devices as well as to eliminate the problem of changing or recharging batteries, antennas should be able to efficiently harvest energy from the environment. This is particularly important for long-term implants.

In order to obtain antennas fulfilling these difficult requirements, different solutions will be investigated during the project:

1. **Investigation of new antenna structures.** In order to reduce the antenna dimensions, different approaches acting on the antenna structure will be considered. On one hand, by exploiting their space-filling property, fractal shapes will be used to directly model the antenna radiating part. On the other hand, the introduction into the main geometry of additional elements like short circuits (as in PIFA or wire-patch antennas), reactive elements or metamaterial-based structures will be also considered.
2. **Use of innovative materials.** In addition to high permittivity dielectrics, new magneto-dielectric materials with permeability different from one will be used to pursue antenna miniaturization. With respect to the first ones, these materials allow the reduction of losses in the operating band, and thus an increment of the overall antenna efficiency.
3. **Development of automatic optimization procedures.** Given the complexity of the antenna structures that will be implemented, the design through standard parametric studies would be too computationally expensive. Consequently, automatic synthesis procedures based on nature-inspired global optimization techniques will be implemented.
4. **Development of multi-band solutions.** To enable improved services like wake-up controlling or wireless power transmission, multi-band antennas are required.
5. **Addition of frequency reconfigurability.** Multi-band/multi-mode operation can also be obtained by using a single-band antenna with frequency reconfiguring capabilities. Solutions based on the use of traditional active elements as well as MEMS components or voltage controlled ferroelectric materials with tunable dielectric permittivity will be considered.
6. **Addition of energy harvesting capability.** For implants where the energy has to be collected from the environment, the antenna must integrate a rectifier to provide RF-to-DC conversion. The result is a rectenna able to supply electrical power to the implanted device.

The developed solutions will be implanted and tested into laboratory mice, thanks to LEAT collaboration with MATOs (Biologic Mechanism of Bone Tissue Alterations) biology group, which possess experience in dealing with rodents used as testing animals.

### III. Conclusions and Future Developments

The proposed research program is aimed at developing, realizing and testing innovative implantable antenna solutions for E-Health WSN applications.

In the near future, the developed antennas are going to be coupled with different kinds of sensors for the monitoring of biological parameters like pressure, temperature, etc. In particular, the attention will focus on passive sensors, whose functioning is based on RFID-like measurements avoiding the presence of batteries. However, successively, the research will be aimed at the development of efficient systems able to directly use the antenna to perform the sensing, thanks to the realization on materials sensible to the parameter to be measured. In addition to the monitoring of biological parameters, the developed devices will be used also to constitute identification and localization systems, which are going to allow the study of the patient behavior as well as the reduction of lacks typical of certain pathologies like Alzheimer or Parkinson.

Successively, the developed solutions will be modified in order to be suitable for human beings implants, and the project will head towards the development of new networks concepts like Inner Body Area Network (IBANs) and the integration into very small animals like insects.

Finally, it is worth to notice the intrinsic multidisciplinary of the project. The monitoring, localization and identification by means of implanted sensors will improve the development of therapies (medicine), the knowledge of biological phenomena (biology) and the study of the animal as well as human being behavioral models (ethology and social sciences). The current and future development of specific applications from these domains will certainly extend the perspectives and research opportunities of the proposed project.

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