Implanted Antenna for Biomedical Applications

F. Merli*[1], L. Bolomey[2], E. Meurville[2], and A.K. Skrivervik[1]

[1] Laboratory of Electromagnetics and Acoustics

[2] Laboratory of Microengineering for Manufacturing 2

Ecole Polytechnique Fédérale de Lausanne, Switzerland

e-mail: francesco.merli@epfl.ch

Abstract

In this paper we present the design, realization and measurements of a first prototype of a complete implantable device. The RF system, working over the *Medical Implanted Communication Systems* (MICS) bandwidth and composed of the antenna, the battery, the transceiver for the data communication and the insulation material, has been designed and realized in order to be integrated with an implanted glucose sensor.

Introduction

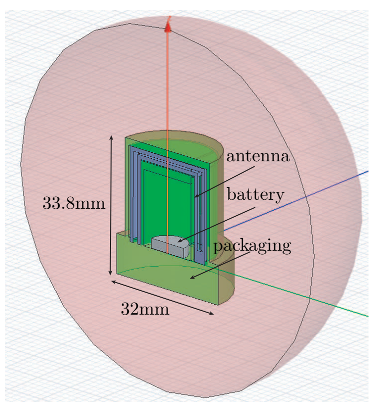
The use of antennas is not uncommon in biomedical devices; imaging systems for diagnostic purposes, radiotherapy systems and body-worn safety devices are nowadays known and, in some cases, widely used. On the other hand, implanted devices have not been widely applied yet, and their use has up to now been concentrated mainly around hyperthermia applications. Recently a high interest has arisen on the implanted device [1, 2], after that both Federal Communication Commission (FCC-USA) and the European Telecommunication Standards Institute (ETSI) allocated the MICS bandwidth [3, 4] from 402 to 405 MHz. The MICS frequency band has been chosen to reduce the wave attenuation in the complex human environment. Indeed the human body is composed of several lossy media with different properties [5] and the allocated frequency band results in sustainable wave attenuation according to the expected thickness of tissue around the antenna.
As a drawback, the use of the MICS band requires electrically very small antennas. Combining all the performance reductions due to the small antenna size and the effect of the lossy environment, the overall resulting system becomes highly inefficient. Nevertheless, the applications for implanted devices are very promising, especially if indoor applications are considered. We present here a first prototype of a complete antenna system including power supply and data communication, designed for an implanted glucose sensor.

Antenna Design

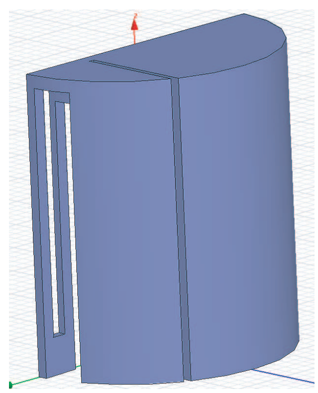
The implanted glucose sensor considered in this application [6] has a cylindrical shape with a long axis; following this structure and to facilitate the assembling process, we designed a conformal antenna, which makes use of the maximal available cylindrical volume.
Starting with the well known (rectangular) planar inverted-F antenna (PIFA), we

978-1-4244-2042-1/08/$25.00 ©2008 IEEE

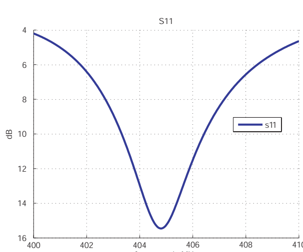
bent the patch and the ground plane in order to create a three dimensional structure, and thus lowered the resonance frequency. The cross section of the structure was then transformed from a rectangle to a circle, and optimized to obtain the required performances. The final structure is depicted in 1(a). The design was performed taking into account the media present in the proximity of the antenna :
- the biocompatible insulation material: PEEK (Polyetheretherketones) with 1mm thickness,
- the human body tissue: we considered an equivalent homogeneous muscle tissue (ϵ_r=57.1, σ=0.79 [5]). The antenna has been simulated in a muscle equivalent sphere (radius 45 mm) in order to estimate the system efficiency [7].
The designed structure moreover provides, due to the folded geometry, a good shielding between the antenna and the electronics that is placed inside, leading to a complete use of the available volume.
Figure 1(c) shows the reflection coefficient of the antenna. It is important to note first that the antenna is not matched to 50Ω, but to the value required by the integrated circuit (IC) produced by Zarlink Semiconductor [8], and second, that the antenna gain is very low (-29dB considering the body presence) due to the very small electrical size of the structure and the lossy environment. However, it satisfies the Zarlink requirements for indoor communication.
In this first prototype, intended to demonstrate the feasibility of the implant, no dielectric was used in order to still reduce the antenna size, which leads to a relatively large implant (cylinder height=22.72mm, external radius=10.5mm). Moreover, in this first attempt, a very simplified model for the human body was considered, where the device is just immerged in a body simulating solution.



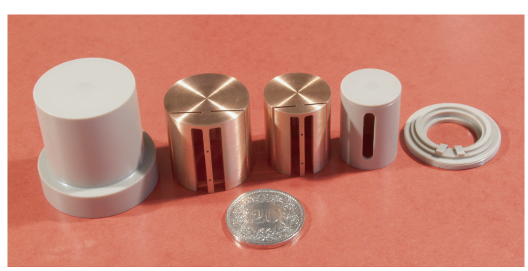
(a) Simulated implant (half)



(b) Simulated antenna (half)



(c) Reflection coefficient



(d) Antenna pieces

Figure 1: Model, realization and results

Electronics and Packaging

As previously mentioned, the antenna was designed to be integrated with the battery for the power supply and a IC. Both mechanical and electrical requirements have been taken into account while designing these components and the required pieces for the insulation. As shown in figure 2, the available empty space inside the antenna has been used to place all active and matching elements. In order to be able to carry out several measurements, the battery life was increased using a large battery (the height is 10.8mm and diameter is 11.6mm, 155mAh) which would be replaced by a smaller device in a real life application, figure 3(a). The large battery was necessary for testing purposes, as it gave us enough autonomy (31 hours of life time)to test several link aspects, using different sub-bands and adjusting matching structures in order to obtain the best performances. After the calibration measurements, that have shown a good agreement with the simulated results, we completely insulated the system.

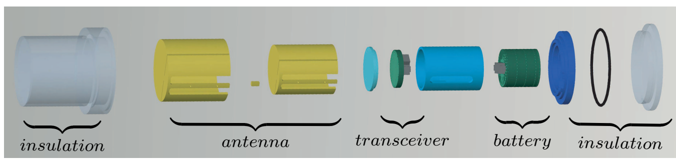


Figure 2: Packaging

Realization and Measurements

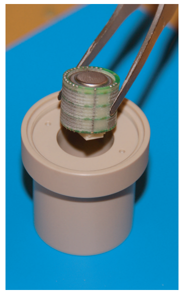
The designed antenna and all the related pieces are shown in figure 1(d). Subsequently the complete system has been mounted resulting in the final insulated implant device in the biocompatible casing. In order to measure the performances of the antenna in a human body tissue we prepared a muscle equivalent liquid following the recipe reported in [1]. Although the application is supposed to be under-skin (interstitial liquid) we decided to test the system in the MICS standard medium (muscle) but with a reduced thickness to consider an environment closer to the working condition; in fact the system has been immerged in muscle equivalent liquid contained in a cylinder, where the antenna is surrounded by roughly 1 cm of liquid on all its sides. The dielectric properties of liquid have been measured using the HP Dielectric Probe Kit 85070E, and we obtained a good agreement with the foreseen quantities, as shown in tab. 1. Placing the antenna into the equivalent body

Body phantom target values (MICS)	Measured values
ϵ_r=57.1	ϵ_r=57.0680
tan δ=0.622	tan δ=0.6573

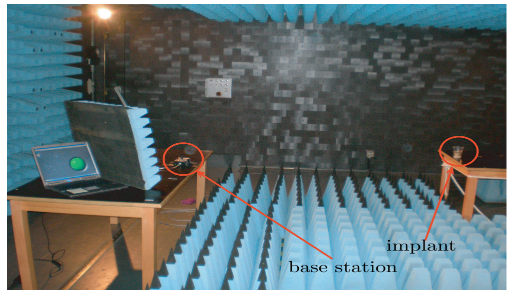
Table 1: Body Phantom

liquid and using the base station provided by Zarlink to transmit data (800Kbps) over the MICS band, we could test the communication link in an anechoic chamber. Figure 3(b) shows the measurements setup.

The base station, controlled by a laptop, is able to send a wake up signal and to start the communication in the MICS band. Several distances, orientations and liquid quantities have been tested showing a maximum range of about 4 meters and a minimum range always larger than 2 m, which is the reading distance specified by Zarlink.



(a) Battery



(b) Measurements setup

Figure 3: Realization and Measurements

Acknowledgements

The authors would like to acknowledge Claudia Bello, PhD student at *Laboratory of Glycochemistry and Asymmetric Synthesis* (LGSA-EPFL) for the help she gave to prepare the required body phantoms. We would like also to thank both the *Atelier de l'Institut de production et robotique* and *Atelier d'électromécanique* (EPFL) for the realized prototypes and the *Power Systems Laboratory* (LRE-EPFL) where the measurements have been taken.

References

[1] P.S. Hall, Yang Hao, Antennas and Propagation for Body-centric Wireless Communications, Artech House, 2006.

[2] Yahya Rahmat-Samii, Jaehoon Kim, Implanted Antennas in Medical Wireless Communications, Morgan and Claypool Publishers, 2006.

[3] 47 CFR 95.601-95.673 Subpart E, Federal Communications Commission 1999.

[4] ETSI EN 301 839-1. 07-2007.

[5] C. Gabriel, Compilation of the dielectric properties of body tissues at RF and microwave frequencies, Report N.AL/OE-TR-, Brooks Air Force Base, Texas (USA), June 1996, http://niremf.ifac.cnr.it/tissprop/htmlclie/htmlclie.htm.

[6] S. Künzi, Viscosity based implantable glucose sensor, Ph.D. Thesis, 2007.

[7] J.F. Zürcher, O. Staub, A.K. Skrivervik, Accurate Measurement of the Maximum Gain of Electrically Small antennas, MOTL, vol. 23, No. 6, December 1999, pp. 328–331.

[8] Integrated Circuit ZL70101, http://www.zarlink.com.