nano-tera.ch
swiss scientific initiative in health / security / environment systems

BioAnt / i-IronIC NTF/RTD 2010

FNSNF

Wireless Power Transfer for Implantable Sensors @ 2.45 GHz – Safety and Design Issues

Jovanche Trajkovikj[1], Onur Kazanc[2], Francesco Merli[1], Catherine Dehollain[2], Anja Skrivervik[1]

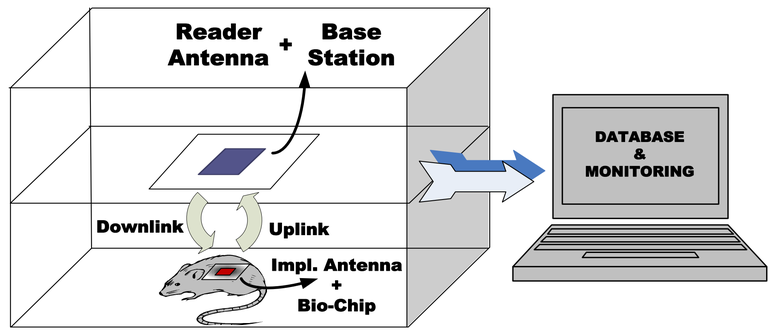
EPFL – LEMA[1], EPFL – RFIC[2]

Laboratoire d'Electromagnétisme et d'Acoustique

Wireless remote powering enables deployment of implantable sensor systems inside living animals or human patients in need of continuous bio-monitoring.

Having a remote base station providing power for operation and data communication, sensor systems do not require internal energy sources. Therefore, they operate independently of battery lifetime.

In this work we focus on small animals monitoring (e.g. mice). Far field remote powering and data communication occur in the ISM 2.45 GHz band. The communication is established within a smart cage (< 1m size) and the complete system is connected to an external processing unit.



Regulations & Safety

Wireless power transmission should comply with [1-3]:

- **Base Station radiation limits (EIRP)**
- **EM exposure Limits**
- **Specific Absorption Rate (SAR)**
- **Temperature raise**

$EIRP = +27\ dBm$ ✓

$\mathrm{Re}\{S_{in}\} = 6.06\ W/m^2$ ✓

$SAR = 0.392\ W/kg$ ✓

$\Delta T = 0.151^0 C\ after\ 120$ s ✓

while providing enough power for the implantable system.

Conservative Link budget analysis

$$P_{out} = \mathrm{Re}\{S_{in}\}\ \frac{\lambda^2}{4\pi}\ G_{rx}\ \tau\ \eta_{rect}$$

S_{in} = Poynting vector at the mouse surface

λ = free space wavelength (12.24 cm at 2.45 GHz)

G_{rx} = impl. antenna gain ≥ - 4.5 dBi (with body losses)

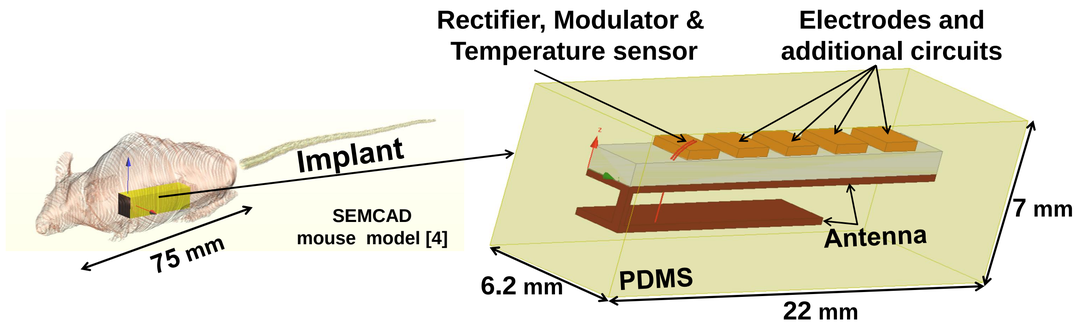
τ = power transmission coefficient ≥ 0.7 (to rectifier)

η = rectifier efficiency ≥ 0.2

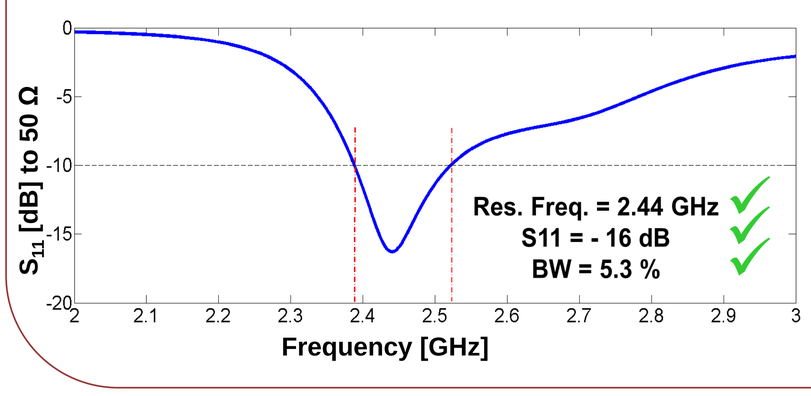
$P_{out} = 0.355\ mW$

Design of implantable antenna @ 2.45GHz

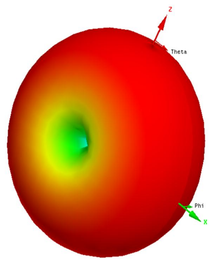
- **Implant size is in a compliance with the real mouse model**
- **Integrated circuits (IC), electrodes, and the antenna are completely encapsulated in a flexible and fully biocompatible material, Polydimethylsiloxane (PDMS)**



- **Antenna is well matched @ 2.45 GHz**
- **The BW covers completely the targeted ISM frequency range**
- **Antenna Gain fulfils system power requirements complying with the regulation & safety specifications**



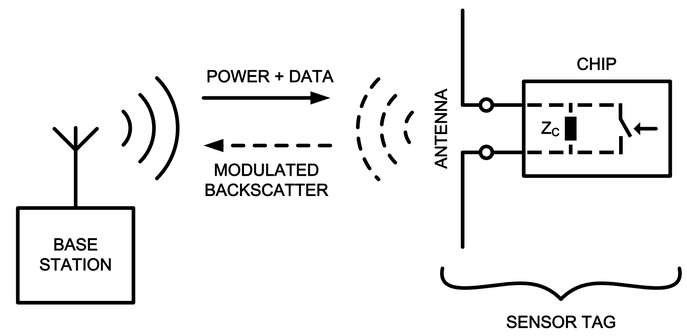
Antenna radiation pattern



Max Gain - 1.2 dBi ✓

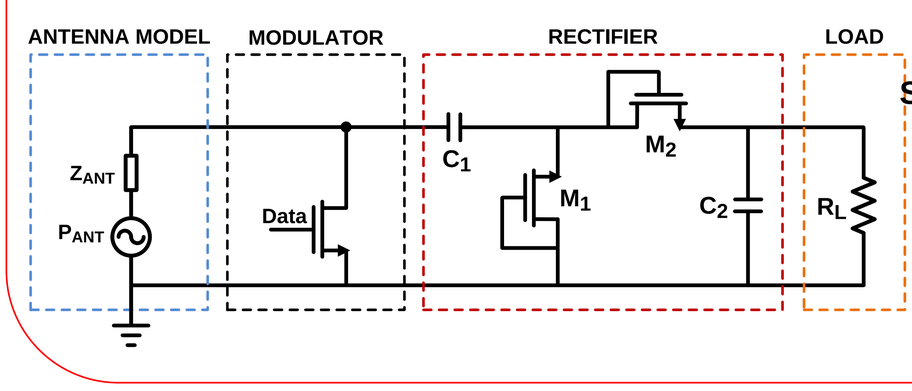
Circuit Design for RF Energy Harvesting

The antenna is combined with a rectifier to realize a "rectenna" as the energy harvesting unit of the sensor (tag). Single operation frequency at 2.45 GHz is utilized to perform wireless remote powering with data communication by backscattering modulation.



Rectifier and modulator are designed to satisfy system specifications:

- **Input power P_{in} is in compliance with the regulations**
- **Desired power efficiency η > 20% and output power P_{out} < 500 μW**
- **Target input impedance Z_{in} = 30 – j250Ω, thus τ > 0.7**



Simulation Results:

P_{in} = 1mW ✓

η = 51% ✓

τ > 0.95 ✓

P_{out} = 484 μW ✓

Conclusion & Future work

- **Simulated performances overcome the conservative analysis, thus ensure a power transmission of more than 400 μW**
- **Realization of antenna prototypes**
- **Fabrication and testing of the energy harvesting IC system**
- **Integration of the components**
- **In-vitro characterization and in-vivo experiments**

References:

[1] ERC RECOMMENDATION 70-03 RELATING TO THE USE OF SHORT RANGE DEVICES (SRD) 2011.

[2] ICNIRP Guidelines FOR LIMITING EXPOSURE TO TIME-VARYING ELECTRIC, MAGNETIC, AND ELECTROMAGNETIC FIELDS (UP TO 300 GHz) , 1998.

[3] IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz, 2005.

[4] ITIS FOUNDATION http://www.itis.ethz.ch/services/anatomical-models/animal-models/.