Measurement Performance for an Implantable Rectenna at Sub-GHz region

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***Abstract*—In this work we analyze the fabrication and measurement of an optimized rectenna. The antenna has been introduced before and is based on a slot printed design. The system covers the two band, 403MHz MedRadio and 915MHz ISM band. Measurements include the printed antenna, input impedance and the rectifying circuit. Measurements havel very good agreement with the simulations**

Keywords—rectifier; MedRadio, ISM, energy harvesting

I. Introduction

Implantable miniature antennas support communication with external health monitoring equipment, wireless transmission of information, including cardiac beat, blood pressure, glucose, and body temperature. Indeed, miniaturized antennas operating in the 400MHz – 2500MHz have been proposed in several configurations for supporting wireless biotelemetry. For example in [1] a planar antenna operating in the 400MHz MedRadio Band has been proposed while in [2] a miniaturized planar dipole has been introduced for in-body communication at the same frequency and a wire dipole antenna has been developed in 950MHz region [3].

While data telemetry has been greatly investigated, there is research deficiency on the implementation of RF wireless power transfer to implanted bio-devices. On the other hand, inductive wireless transfer for implanted devices has been studied a lot. Mainly, it has been based on coil configurations systems in very close distances in-between (in terms of wavelength). Still, the use of inductive loops requires distances between external applicator and implanted receiver of 1-2 cm [4], [5] and therefore placement of the external applicator directly on the body. Moreover, displacement of the external applicator or unwanted misalignment between external and internal system can greatly affect wireless transmission performance. In any case, such problems have been addressed but not necessarily solved.

RF wireless power transfer can alleviate such problems. Use of antennas for wireless energy transmission can achieve greater distances in robust designs combined with greater efficiencies. Designs are based on rectennas. The implantable rectenna receives and converts RF energy collected by the implanted antenna into useful power for the biologically-embedded medical systems. In [6], an implantable antenna was designed for wireless data telemetry (MedRadio, 402 MHz), power transmission (ISM, 433 MHz), and wake-up signal operation (ISM, 2.45 GHz). An impressive conversion efficiency of 86% was reported when the antenna input power was 11 dBm and the load was 5 kOhm at 433 MHz. However for typical distances of 1 meter, efficiency drops considerably and the proposed antenna is relatively thick. A compact single-band implantable PIFA with a rectifier has, been also suggested for wireless powering (ISM, 2.45 GHz) in [7]. A parasitic patch over the human body was designed for increased antenna gain, and, therefore, enhanced received power. A conversion efficiency of 42% was, then, obtained at -10 dBm input power and for 3.25 kOhm load.

In [8] a novel minaturized rectenna for wireless telemetry and power transfer at MedRadio (402-405MHz) and ISM (902.8-928MHz) bands, correspondingly, has been proposed. A single-layer PIFA was adopted as the radiating element aiming at antenna structure simplicity and low-profile. A rectifier system has been proposed taken into account power link calculations and patient safety considerations. A conversion efficiency of 33.1% is achieved at received antenna power of -16 dBm and for 9.5 kOhm load at 915 MHz. The antenna along with the rectifier were further optimized in [9] and 40% efficiency was achieved by appropriately modifying the rectifier.

Here we present further steps taken to measure and fabricate the final proposed design. Conclusive measurements of the system will be presented in the conference.

II. Proposed System

Proposed system is given in Fig 1. Antenna is coupled (matched) to a rectifying circuit through an input filter. The rectifier is then matched to the load for optimum efficiency. The antenna designed is presented in [8]. The antenna is printed on a Rogers RO 3210 substrate (ε_r=10.2, tanδ=0.003, t=0.625 mm) and is covered with an identical superstrate. More details can be found in [8]. High Frequency Structure Simulator (HFSS) is used for antenna design and analysis [10].

Antenna is placed at a depth d=10 mm of a cylindrical three layer (skin-muscle-bone) model representing an arm. The simulated far-field gain pattern is prety robust and not affected by the antenna position into the arm. At 10mm depth, the maximum gain is calculated to be -35.6 dB for the MedRadio band and -23.4 dB for the ISM band respectively. In both frequency bands, the radiation pattern is nearly omnidirectional. More details for the antenna can be found in [8], [9].

III. Antenna performance

In Fig. 2 the measured return loss of the antenna is presented for the ISM (915MHz) band. The comparison with simulations reveals a very good agreement. It is noted that antenna is simulated in muscle tissue. Measurements are carried out for the antenna implanted into minced beef.

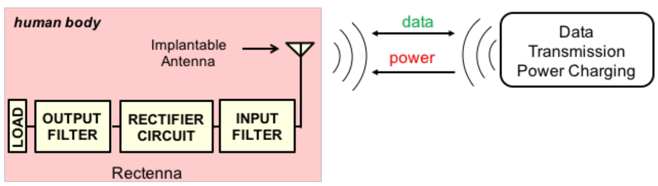

Fig. 1. Configuration of proposed system. Implantample antenna is matched to a rectifier and carries out thus two operation.

IV. Rectifier

The rectifier converts RF energy collected by the implanted PIFA into useful DC power. It consists of an input filter, a rectifying circuit, an output filter and a load. Here we present the rectifying circuit along with the parallel load / capacitor scheme. As shown in Fig. 3 two rectifying circuits were tested. Beside the usual double diode converter a single diode converter is tested. The input of the circuit consists of a chip capacitor and inductor, while, the rectifying circuit is a Schottky voltage doubler, or single Schottky voltage converter. Optimized off-the-self elements are used.

Circuits were extensively analyzed through ADS, taking into account transmission line length, company-provided S-parameter files for the capacitors, inductors and diodes before fabrication and testing. Measurements were performed by feeding the circuits with a power vector generator and a digital multimeter. Measured voltage is presented in Fig. 7. As seen there is impressively good agreement between measurements and simulation. A disagreement occurs at the highest values of power input where a saturation is expected but it is not observed.

Finally, measurements for the integrated system consisting of the rectifier, the antenna and the load will be carried out. The generator signal will pass through an amplifier to the external antenna that will be placed at 1 meter distance from the implanted antenna. A digital multimeter connected to the load will record the voltage. The rectifier circuit will be integrated at the bottom of the antenna, protected from the ground plane.

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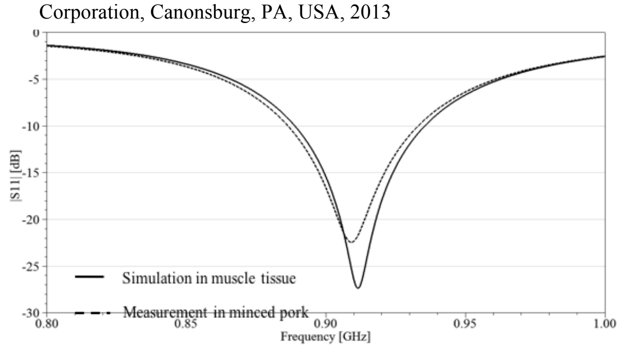

Fig. 2. Measurement of antenna and comparison with simulations at 915MHz.

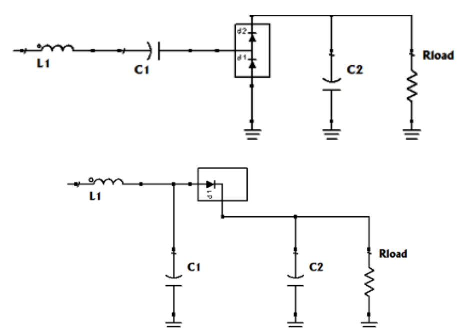

Fig. 3. Doubler (top) where L_1= 22nH C_1= C_2=27pF, R_{load}=2.5kOhm, and single DC converter (bottom) where L_1=39nH C_1=0.5pF, C_2=12pF, R_{load}=2kOhm coupled to the load for the rectenna.

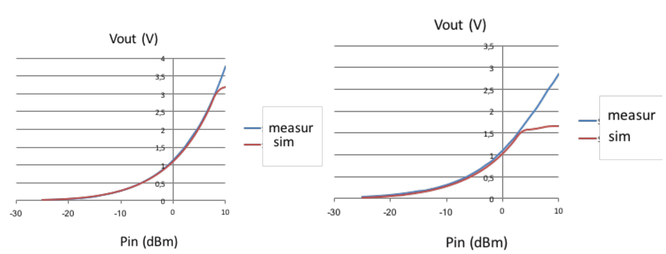

Fig. 4. Measured voltage as compared with simmulated one for the Doubler (left) and single DC converter (right)