Powering implants by galvanic coupling: a preliminary analysis

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1. Introduction

While galvanic coupling for intrabody communications has been proposed lately by different research groups [1], its use for powering electronic implants remains almost non-existent despite it is an effective method, as we have recently shown *in vivo* [2]. Reluctance to use galvanic coupling for power may arise from not recognizing two facts. First, large magnitude high frequency (f) currents can safely flow through the human body if applied as short bursts (duration = B, repetition rate = F). Second, an adequate voltage can be obtained across the two pick-electrodes by shaping the implant as a thin and flexible elongated body (Figure 1), which is configuration that allows minimally invasive percutaneous deployment. Here it is presented an analytical model to compute the attainable power by galvanic coupling.

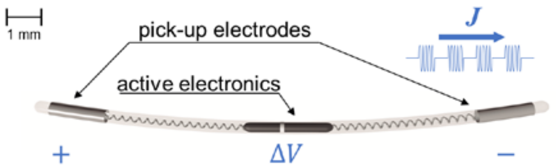

Figure 1. *We envision thin and flexible implants powered by innocuous high frequency current bursts through tissues.*

2. Methods

IEEE and ICNIRP safety standards for human exposure to electromagnetic fields recognize that at $f \geq 10$ MHz Joule heating is the only source of risk caused by current passage. The heating limitation is indicated as a limitation to the so-called Specific Absorption Rate (SAR), which can be calculated as:

$$SAR = \frac{\sigma (E_{RMS})^2}{\rho} = \text{(for ac bursts)} = \frac{\sigma \left(E_{peak}\right)^2}{2\rho} FB$$

where σ is the electrical conductivity of the tissue (S/m), ρ is the mass density of the tissue (kg/m^3) and E_{RMS} is the RMS value of the electric field in the tissue (V/m). In most relevant scenarios, the SAR limit is 10 W/kg.

Here it is modeled the delivery of current bursts which produce a SAR of 10 W/kg and it is obtained the time averaged power that ideally could be ohmically drawn by implants with length L. For obtaining closed analytical expressions, the implant electrodes are simply modeled as spherical electrodes with diameter D.

Coupling between the tissue and the implant electrodes is modeled with a Thévenin equivalent. The open circuit voltage is that that appears across the electrodes locations when the implant is not present. If the implant is aligned with the electric field ($E(t)$), then $\mathrm{V_{TH}}(t) = LE(t)$. The equivalent resistance ($\mathrm{R_{TH}}$) is the resistance of the dipole formed by the two electrodes. If $L \gg D$, $\mathrm{R_{TH}} = 1/\pi\sigma D$.

Then, taking into account that the power drawn by the implant will be maximum when its resistance equals $\mathrm{R_{TH}}$, it can be found that this maximum power for a given SAR limit (SAR_{max}) is:

$$P_{max} = \frac{\pi}{4} SAR_{max} \rho L^2 D$$

3. Results

The results presented in Figure 2 correspond to the case of muscle tissue (ρ = 1060 kg/m^3). Very similar results are obtained for other soft tissues as densities are similar.

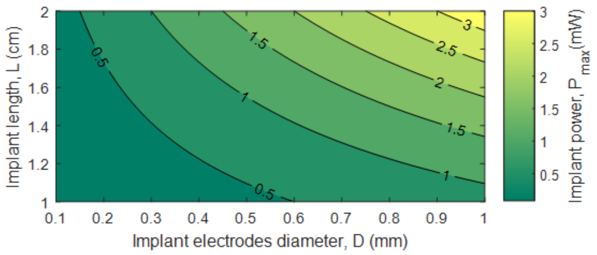

Figure 2. *Power that ideally could be drawn by an implant in muscle for applied current bursts with a SAR of 10 W/kg.*

4. Conclusions

The obtained results show that powers above of 1 mW can be obtained in short implants when currents which comply with safety standards flow through the tissues where the implants are located. In addition, it is worth noting that the analytical expression obtained for P_{max} is independent of the tissue conductivity (σ) and also of the duration (B) and repetition frequency (F) of the bursts.

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References

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