Transcutaneous Dual Tuned RF Coil System Voltage Gain and Efficiency Evaluation for a Passive Implantable Atrial Defibrillator

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Atrial fibrillation (AF) is the most common cardiac arrhythmia, affecting 1% of the world population. Cardioversion of AF can be achieved by applying an electric shock to the heart (defibrillation). A cost-effective approach for internal cardioversion is by means of a subcutaneously implanted passive defibrillator. Methods: A circuit performance study for transcutaneous methods of atrial defibrillation is presented. A circuit design using a dual tuned resonant circuit whose capacitance also serves as a voltage booster is proposed and evaluated. Because of the rectifier network, the proposed circuit presents different secondary topological configuration for the positive and for the negative half cycles, leading to a complex theoretical analysis problem. Therefore, PSpice simulation and MatLab based modelling was implemented for circuit performance characterisation. Measurements were implemented on a hardware prototype circuit to verify the validity of the simulations and modelling results. The overall system efficiency study was carried out for several coil dimensions using a simple analytical model for the RF coils. For this particular task, a MatLab program for estimating the link efficiency was implemented. Results: The stability of output voltage across a 50 ohm heart model was evaluated by determining its variations as a function of coil separation. The circuit exhibited inherent voltage gain stability with changing separation at certain operating frequencies, with a reasonable voltage gain level $>$0.3 (Vrx/Vtx). Computed link efficiency modelling, estimated high link efficiency values of about 63.63% at resonant frequency (208 kHz) and 26 mm separation. Overall system efficiency was measured for the hardware prototype circuit, obtaining 59.61% in the best case, justifying the proposed circuit design. The study results would also suggest using a smaller (diameter) receiver coil on the implanted side while placing a larger coil on the transmitting side; this particular arrangement would be more suitable in an implanted passive defibrillator design.