On the Design of Efficient Magnetic Coils for the Stimulation of Peripheral Nerves

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Neural stimulators are the key building blocks of current neuroprosthetic systems, such as cochlear and retinal implants. Due to direct current injections and foreign body reactions, conventional current passing electrodes suffer from reduced performance and reduced lifetimes. However, magnetic fields can be used as an alternative technique to induce currents in neural tissues with the goal of stimulating the central and/or peripheral nervous systems (M. Yamaguchi et. al., *JAP*'89). Because the effectiveness of magnetic stimulation is directly related to the magnitude of the generated magnetic fields resulting from the current carried by a magnetic coil, the magnetic coil needs to be optimized to enhance the induced electric field at the stimulus site.

Despite the attractive feature of minimally-invasive stimulation at the targeted nerve, current magnetic stimulation coils are very large (3-5 cm diameter) compared to conventional current passing electrodes and require significant energy threshold for the stimulation (~200-350 Joules). To achieve more focused neural stimulation, a more optimal magnetic coil can be designed by numerically predicting the field distribution near the coil. In this work, numerical models are developed for different coil configurations (solenoid and figure-eight) with various dimensions. To validate the numerical models, optimal coils have been built and stimulated. The voltages induced at the terminals of a small probe coil were compared with simulations.

In order to excite a neural response, induced electric fields are related to the coil current magnitude and the stimulus pulse duration. To compare numerical and experimental results, the induced electric fields and pulse widths were measured as a function of these parameters. The simulation predicted the induced field magnitude and pulse duration within 5% of the experimentally measured values.

Finally, the application of numerical models for optimizing the magnetic coil for low power consumption and effectiveness for use in an animal model is discussed. The output waveforms of these models were used as activation functions in an active nerve model to predict the stimulus threshold. Preliminary in-vitro experiments show that such optimally designed magnetic coils can be used to evoke magnetic stimulation of the frog sciatic nerve with energy thresholds less than 50 Joules.

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