Computational Finite Element Model to Compare Voltage and Current Controlled Deep Brain Stimulation Systems.

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TRADITIONALLY, deep brain stimulation (DBS) systems have used voltage stimuli, and clinicians are familiar with them; recently, current controlled devices appeared on the market and are subject of comparative investigations to determine their advantages and drawbacks. The aim of our research is to quantitatively compare the spatial distribution of the electric field generated in the brain tissue using voltage or current controlled stimulation. From an electrical engineering perspective, the parameters under examination can be separated in three parts: the neurostimulator circuitry, the stimulating electrodes characteristics (size, geometry, material, etc.); and the electrical characteristics of brain tissue (electrical conductivity and relative permittivity) [1].

The present investigation relates these three parts in an axisymmetric two dimensional computer model of a quadripolar DBS lead (Fig.1, left); the model has been built using COMSOL Multiphysics 4.3a (COMSOL AB, Stockholm, Sweden). The neurostimulator circuitry is modeled with an ideal voltage or current source; the electrode is based on Medtronic quadripolar lead 3389 (Medtronic Corporation, Minneapolis, MN, USA).

Regarding the tissue, two explorations were performed: a) tissue modeled as an isotropic and homogeneous material with an electrical conductivity similar to that of the grey matter, and b) grey matter plus a 0.5 mm medium surrounding the shaft mimicking the cerebrospinal fluid which may leak when the lead is inserted [2].

The evaluation is based on the measurement of the electric field at 1 mm from the shaft of the DBS lead and also on the measurements of the maximum distance reached by the electric field based on different stimulation values.

The results show that the electric field generated by voltage controlled stimuli is more susceptible to changes in the medium characteristics (Fig. 1, right). Current stimuli show a more uniform response regardless of the medium (Fig. 1, right).

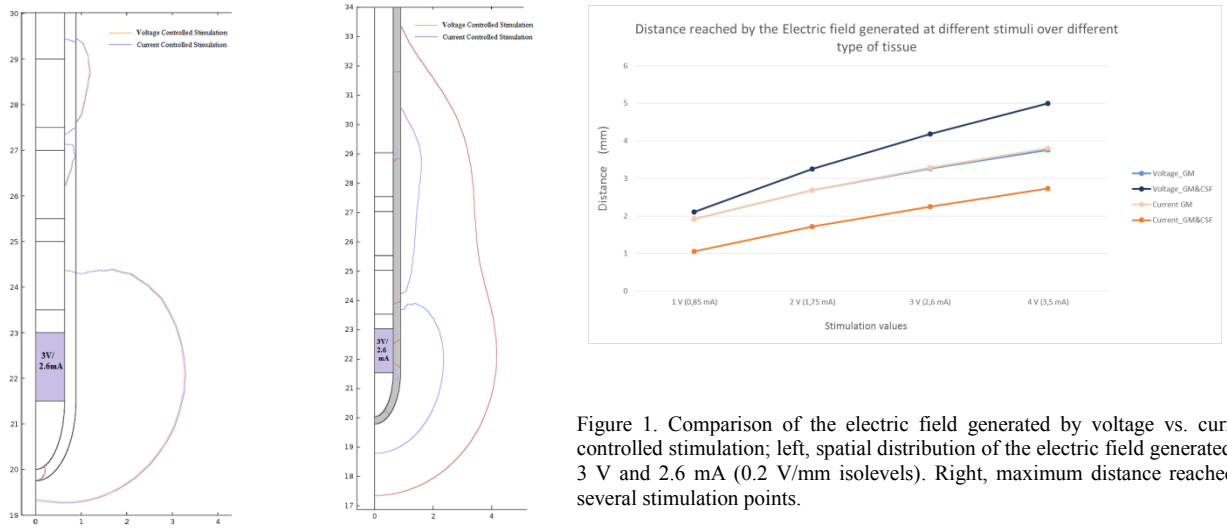

Figure 1. Comparison of the electric field generated by voltage vs. current controlled stimulation; left, spatial distribution of the electric field generated by 3 V and 2.6 mA (0.2 V/mm isolevels). Right, maximum distance reached at several stimulation points.

REFERENCES

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