Magnetic Stimulation Alters Conduction Profiles in Ephaptic Tracts

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Abstract

In this note the authors demonstrate the alteration of action potential propagation in a tract of two axons, when they are stimulated by a magnetic field in the x-y plane.

For simplicity, in this work we use Ampere's law without Maxwell's correction term. We specify a magnetic field oscillating in the x-y plane. The resulting current density is directed in and non-zero only in the z-direction. All fields and current densities are modeled in a 3D volume of points. The volume contains two ephaptically interacting axons, aligned along the x-axis. Thus the current injection is into the nodes of the axons. The axons are assumed to be minimally separated, with a separation equal to the minimum allowed value. Thus adjacent rows of the current density z-component matrix act as additional stimuli, over and above the usually injected stimulus. All stimuli are treated as input only at the first node. In future work, the TMS induced stimulus should be allowed into every node of the two axons.

We find that the oscillations of the B-field generate a spatially varying current density z-component. This leads to speeding up of the action potentials on the second axon with respect to the control case of no-TMS. Figure 1 shows the case without TMS and Figure 2 shows the case with TMS.

There are papers such as [1], which mention that in multiple sclerosis (MS) conduction slows down and TMS can correct for this. Though the mechanisms they suggest are more varied than mere additional stimulus induced by TMS, their conclusion appears to be bolstered by our result - if conduction slows due to MS, and TMS speeds it up, then it can be used as a treatment modality.

This validation is important because it is based on a rigorously created MATLAB simulation of the partial differential equations involved in coupled propagation of action potentials in a tract of axons [2, 3].

References

[1] Xiaoliang Zhou, Kailin Li, Si Chen, Wenbin Zhou, Jing Li, Qing Huang, Tingting Xu, Zhiyuan Gao, Dongyu Wang, Shuo Zhao, et al. Clinical appli-

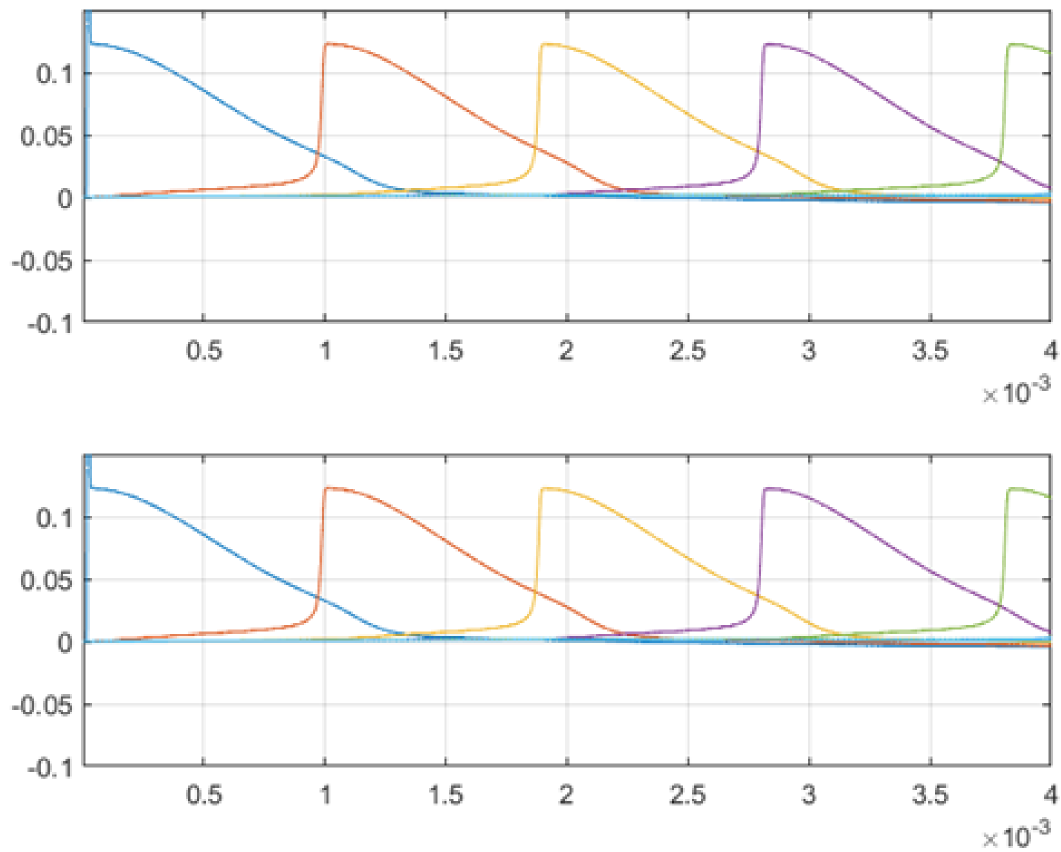

Figure 1: The case without transcutaneous magnetic stimulation.

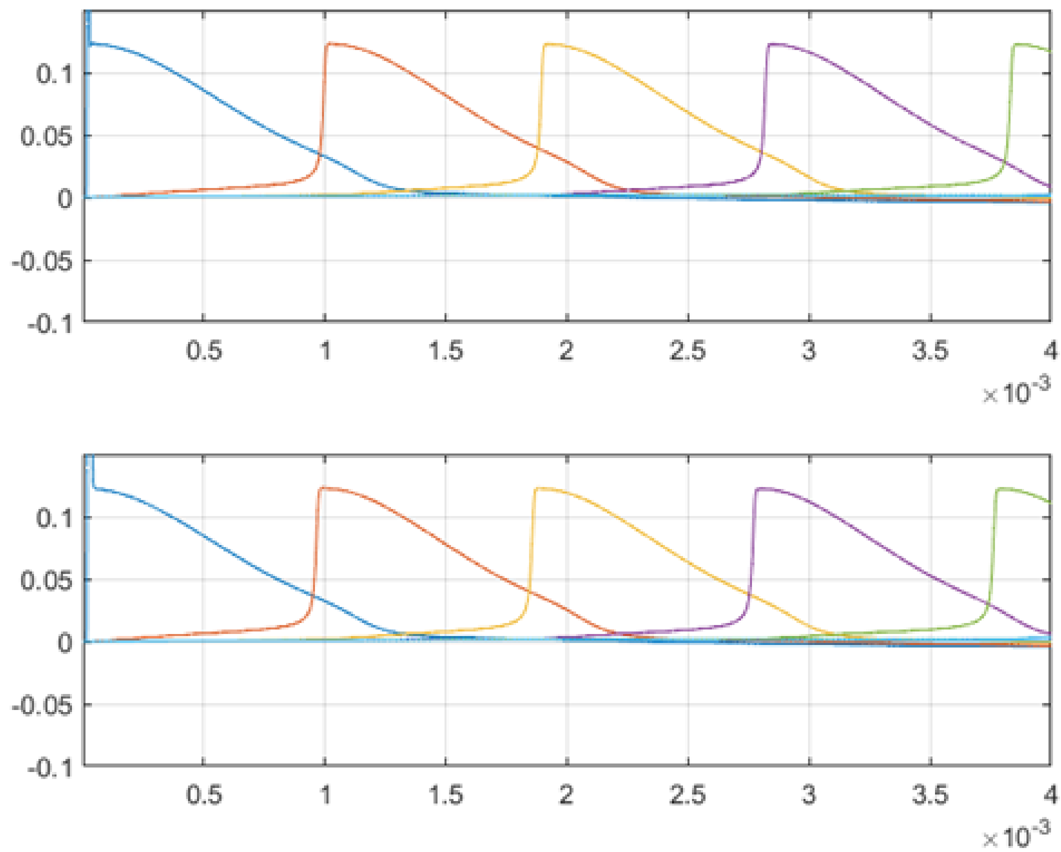

Figure 2: The case with TMS.

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[2] Aman Chawla, Salvatore Morgera, and Arthur Snider. On axon interaction and its role in neurological networks. *IEEE/ACM Transactions on Computational Biology and Bioinformatics*, 2019.

[3] Aman Chawla, Salvatore D. Morgera, and Arthur D. Snider. Fields, geometry, and their impact on axon interaction. *Journal of Applied Mathematics and Physics*, 9(4):751–778, 2021.