The Magnetic Field Distributions from a Propagating Action Potential: Supplementary Results

Prepared by:
Mark Trew & Andrew Pullan

Auckland Bioengineering Institute
The University of Auckland
New Zealand

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1.0 Introduction

These supplementary results have been obtained by modifying both the domain and the extracellular conductivities of the problem reported on 23 January 2007. These modifications were made to confirm that an effective monodomain solution resulted in negligible magnetic flux density fields.

2.0 Methods

The methods were mostly identical to that reported previously. Variations and additional information that was not included previously are reported below.

2.1 Computational Mesh

The central tissue core from the previous work was retained and the domain below the tissue core (containing the anode) was converted from bath to tissue properties. The discretization of the reduced domain was identical to the previous models. The total number of computational points in this reduced model was 2989833.

2.2 Computing Electric Potentials

20 ms of simulated time were completed in 1.5 hours of elapsed time using 32 threads on a p590 IBM Regatta (52 hyper-threaded Power 5, 1.9 GHz processors and 210 Gb shared memory). Membrane currents during the activation phase were modeled using a cubic relationship between current and transmembrane potential [1].

2.4 Model Parameters

These supplementary results were computed using the same parameter sets as previous with a fiber direction oriented along the horizontal axis.

2.4.1 Effective Conductivities

Effective Conductivity (mS/mm)	Nominal Anisotropy
σ_{ix}	0.2
σ_{iy}	0.02
σ_{ex}	0.2
σ_{ix}	0.02

2.4.2 Tissue and Membrane Properties

The values used for the tissue and membrane properties were not explicitly presented in the previous report.

Properties	Value
Membrane capacitance	0.01 μF/mm^2
Cell surface to volume ratio	200 1/mm
Resting potential	-85 mV
Plateau potential	15 mV
Threshold potential	-75 mV
Membrane conductance	0.004 mS/mm^2

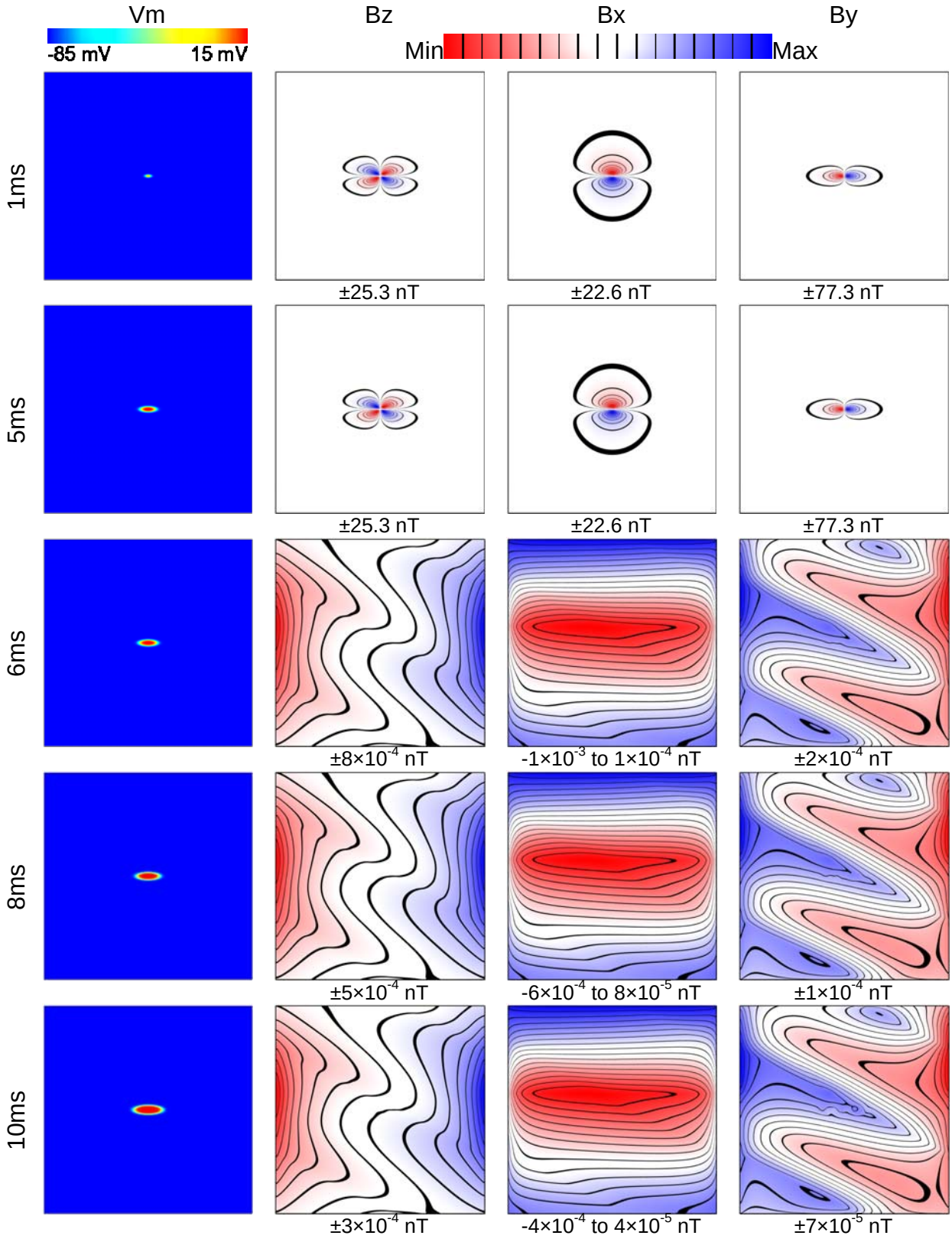
3.0 Results

Transmembrane potential (V_m) and magnetic flux density fields (B_z, B_x and B_y) are shown over a 30 mm by 30 mm window equivalent to the top surface of the tissue slab. The V_m field is from the top surface of the tissue and has not been depth integrated. The B* fields have been computed on a surface 0.15 mm above the surface of the tissue.

These results do not include any effects from the insulator core on the stimulating electrode.

3.1 Equivalent Monodomain Solution

In this problem, the conductivity values were the same in both domains. The color ranges for the magnetic flux components have been set to the min to max field range. Following the termination of stimulation after 5 ms, the components of the magnetic flux are effectively negligible (compared to the results presented in the previous report), with peak absolute values less than 1 pT. Some minor perturbations of the components around the spreading activation wavefront can be seen, particularly 8 ms onwards. The shapes of the post stimulus fields are likely moderated by factors such as: (i) truncation error in the derivative approximations used to calculate the current densities, particularly near the boundaries; (ii) the linear solver residual field; and (iii) the finite resolution of data transferred between the electric potential/current density calculation phase and the magnetic flux density calculations phase.


Vm
-85 mV
15 mV
Bz
Bx
By
Min
Max
1ms
5ms
6ms
8ms
10ms
±25.3 nT
±22.6 nT
±77.3 nT
±25.3 nT
±22.6 nT
±77.3 nT
±8×10-4 nT
-1×10-3 to 1×10-4 nT
±2×10-4 nT
±5×10-4 nT
-6×10-4 to 8×10-5 nT
±1×10-4 nT
±3×10-4 nT
-4×10-4 to 4×10-5 nT
±7×10-5 nT

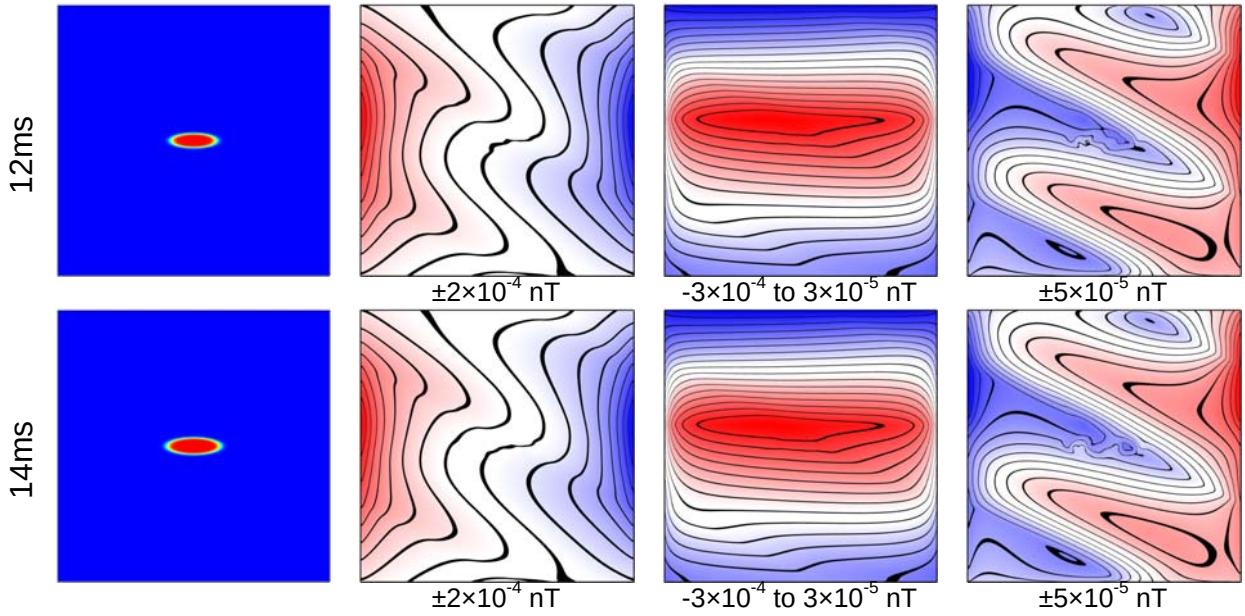


Figure 1. Equivalent monodomain solutions: transmembrane potential fields and magnetic flux density fields over 14 ms.

4.0 References

[1] HUNTER, P.J., McNAUGHTON, P.A., NOBLE, D. 'Analytical Models of Propagation in Excitable Cells.' *Progress in Biophysics and Molecular Biology*, 30(2/3), 99-144, 1975.