Scientific Report

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Period of the fellowship	01/12/2012 to 30/11/2013

I – SCIENTIFIC ACTIVITY DURING YOUR FELLOWSHIP

We are continuously exposed to electromagnetic (EM) fields generated by electronic devices such as cell phones. The effects on human bodies by EM waves, especially ones with the frequency range between 3 kHz and 300 GHz, called radiofrequency (RF), are of great interest. Reported effects of RF fields on living systems are widely variable; harmful, negligible, or nil. Although no definitive evidence has been found, it is generally considered that exposure to low energy RF waves could be a risk to human health. However, some beneficial effects were also reported.

The project I joined is to elucidate the underlying mechanism of the effects of the EM fields to the neurons. I originally attempted to work on a part of the top-down approach; how the generated EM waves near the head penetrate the skull, how the network of the neurons are stimulated (extracellular stimulus), and then if the action potentials occur in each of the neurons. This approach was, however, very difficult, so I worked on a part of the bottom-up approach instead; I explored by simulation what kind of intracellular stimulus would be the most efficient to generate action potentials on a single neuron.

For the simulation, I used the original Hodgkin-Huxley model with a very simple geometry. As the intracellular stimulus, I applied five different alternative currents: square, sine, sawtooth, reverse sawtooth, and triangle waves. The results show that the square wave is the most efficient and the sine is the second best. However, this simulation is not very practical because the mathematical model I used is not realistic for our case.

The Hodgkin-Huxley model was originally developed to explain the propagation of action potentials in the squid giant axon, but what we need to consider is the neuronal network of a human. I have started to do simulations using the Hodgkin-Huxley type model, which was developed for a pyramidal cell in the region of the human brain controlling memory.

I did not have time to work on the simulations with multiple neurons during the term although this was planned; thus the simulation using a more realistic mathematical model with more than one neuron is the next step.

II – PUBLICATION(S) DURING YOUR FELLOWSHIP

1. ***Effects of ion channel currents on induced action potentials***
   by Rié KOMURO and Ilangko BALASINGHAM
   Proceedings of the 6th Annual International IEEE EMBS Conference on Neural Engineering, pp.601-4

Abstract

With development of electric devices, continuous exposure of electromagnetic (EM) fields to human bodies has become great concerns. Despite our interest, their effects on human bodies have not been well-determined. We have an interest in the non-thermal effects of the EM fields on neurons and attempt to establish a scientific explanation. Elucidation of the EM effects on neurons could allow us to make use of the induced current for spike initiation.

As the first step toward understanding the connection between the applied current and the triggering action potentials, we simulated how the generated action potential would change depending on the applied current using a fundamental mathematical

model on a simple geometry. Five periodic waves having different shapes were used as the applied current. Analysis showed that not only how the current increased the value but also how it decreased the value was important. We also concluded that the sine wave would be the best as the applied current among the five to generate action potentials.

References

[1] MH Repacholi. Low-level exposure to radiofrequency electromagnetic fields: Health effects and research needs. *Bioelectromagnetics*, 1998.
[2] GW Arendash et al. Electromagnetic field treatment protects against and reverses cognitive impairment in alzheimers disease mice. *J Alzheimers Dis*, 2010.
[3] EM Izhikevich. Which model to use for cortical spiking neurons? *IEEE Trans Neural Networks*, 2004.
[4] AL Hodgkin and AF Huxley. A quantitative description of membrane current and its application to conduction and excitation in nerve. *J Physiol*, 1952.
[5] W Gerstner and WM Kistler. *Spiking Neuron Models: Single Neurons, Populations, Plasticity*. Cambridge University Press, 2002.
[6] F Mesiti and I Balasingham. Nanomachine-to-neuron communication interfaces for neuronal stimulation at nanoscale. *IEEE J Sel Areas Commun*, 2013.
[7] C Koch. *Biophysics of computation: information processing in single neurons.* Oxford University Press, 1999.
[8] A Mauro et al. Subthreshold behavior and phenomenological impedance of the squid giant axon. *J Gen Physiol*, 1970.

2. ***Electromagnetic Fields for Neuron Communications***
by Rié KOMURO and Ilangko BALASINGHAM
ERCIM Newsletter, vol.2013, no.94, pp.34-5, 2013

Abstract

Are electromagnetic fields harmful to the brain? We are continuously exposed to electromagnetic (EM) fields generated by electronic devices such as cell phones. The effects on human bodies by EM waves, especially ones with the frequency range between 3 kHz and 300 GHz, called radio frequency (RF), are of great interest. Reported effects of RF fields on living systems are widely variable; harmful, negligible, or nil. Although no definitive evidence has been found, it is generally considered that exposure to low energy RF waves could be a risk to human health. However some beneficial effects were also reported.

References

[1] GW Arendash et al. Electromagnetic field treatment protects against and reverses cognitive impairment in alzheimers disease mice. *J Alzheimers Dis*, 2010.
[2] F Mesiti et al. On the modeling and analysis of the RF exposure on biological systems: a potential treatment strategy for neurodegenerative diseases. *Nano Commun Networks*, 2012.
[3] F Mesiti and I Balasingham. Nanomachine-to-neuron communication interfaces for neuronal stimulation at nanoscale. *IEEE J Sel Areas Commun*, 2013.

Our research team is currently working on a book chapter entitled ***Neuro-Spike Communications***.

III – ATTENDED SEMINARS, WORKSHOPS, CONFERENCES

VERDIKT Conference 2013
15 October 2013
Trondheim, Norway

Nano-scale Communication Technologies: status and future perspective
17 October 2013
NTNU, Trondheim, Norway

The 6th International IEEE EMBS Conference on Neural Engineering
6-9 November 2013
San Diego, USA
(Poster presented)

IV – RESEARCH EXCHANGE PROGRAMME (REP)

INRIA (Sophia Antipolis)
France
NeuroMathComp Laboratory
Professor Olivier Faugeras
21-25 October 2013
I had a chance to talked to people in the group as well as other research groups. They explained what they worked on, and some of them gave me informative advice.

CWI
Netherlands
Life Sciences
Dr. Sander Bohte
11-15 November 2013
I gave a presentation and talked with the people in the group. I obtained helpful input to my work. I also attended two seminars.