Trends in brain applications of electromagnetic fields

***Mikael Persson*[1], *Andreas Fhager*[1], *Hana Trefna*[1], Mai Lu[1],**
[1]Department of Signals and Systems, Chalmers University of Technology, Sweden,
mikael.persson@chalmers.se, andreas.fhager@chalmers.se, Hana.Trefna@chalmers.se, Mai.Lu@chalmers.se

Abstract

This paper gives an overview of new trends in the use of electromagnetic fields for medical applications for diagnostics and treatment focusing on brain applications. The trends are exemplified with applications from brain monitoring, source localization, stimulation microwave tomography and hyperthermia

1. Introduction

There are presently considerable strains on the health systems arround the world. With the demographic development with an aging population this is likely to increase calling for new cost efficient technologies. Future detection systems, fore instance, based on microwave sensors, could potentially provide easy access at low costs for a large number of patients. With the recent developments in optimisation and modern algorithms there is a considerable scope for new sensors for medical diagnostics, monitoring and treatment using electromagnetic fields. In this paper this trend is exemplified with examples from tomography, hyperthermia, brain monitoring, brain stimulation and source localisation.

2. Brain monitoring

With recent developments of antenna design and modern algorithms for signal processing, there is a considerable scope for new sensors in medical diagnostics and monitoring using electromagnetic fields at microwave frequencies. It is anticipated that this new technology can provide easy access to diagnosis and monitoring of treatment at low costs for a large number of patients, both for hospitalized and out-patient care.

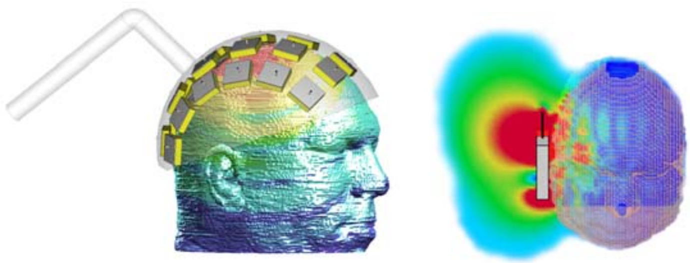

Figure 1. The design and simulations of the brain monitoring system (left) and penetration of the field from the mobile phone in the human brain (right)   the mobile phone in the human brain (right) .

In Sweden roughly 30 000 people/year suffer a stroke, with stroke below 65 years of age increasing and presently constituting 20%. Approx. 85% are ischemic, 10% hemorhagic, and 5% subarachnoidal strokes. Stroke comes third among reasons for acute death, and first among reasons for neurological dysfunction in Swedish health care. Among stroke survivors, 20% have serious remaining dysfunctions. A much larger proportion have less conspicuous dysfunctions which still seriously affect quality of life for the patient and relatives. Among somatic diseases, stroke is the dominating reason for hospitalisation, generating huge health care-related costs. The intriguing aspect of microwave-based monitoring is that its putative ability to differentiate between ischemic and hemorrhagic stroke may abolish the need for a time-consuming cerebral CT delaying therapeutic procedures. Furthermore, the applicability of microwave-based techniques in artefact-rich environments such as moving vehicles open up possibilities for pre-hospital diagnosis and thus minimal delay between impending stroke and early cure.

Figure 2. The microwave based brain monitoring prototype system

3. Brain stimulation

Until a few years ago the prevailing dogma in neuroscience stated that no neurons could be created in the brain after the developmental period. We now know that this is not true, and the birth of new neurons from neuronal stem cells, a process called neurogenesis, have been seen in adult brains from both rodents and humans. The search for ways to control and stimulate this inborn ability of the brain to produce nerve cells is intense, as it has the potential to become very useful therapeutic tools in the future. In sight are possibilities to create therapies where new neuronal cells can replace cells that had succumbed during injury or disease. The problem is now how to achieve this goal in a way that is efficient but without the risk of producing severe side effects at the same time. Based on a hypothesis that endogenous neurogenesis can be stimulated by We present a multichannel transcranial magnetic stimulation (mTMS) system with 40 coils. This mTMS system can be used to stimulate different brain locations simultaneously. The induced electric eld in a 3D human head model by mTMS has been calculated by employing the impedance method.

Transcranial magnetic stimulation uses rapidly changing magnetic fields to induce electric fields in the brain, leading to excitation of neurones. As a non-invasive method to stimulate brain, TMS has attracted considerable interests as an important tool for studying the functional organization of the human brain as well as a therapeutic tool to improve psychiatric disease. Traditional TMS devices operate by energizing one circular or figure-eight-shaped coil that is manually moved the target untill the desired response is achieved [1]. Recently, multichannel transcranial magnetic stimulation (mTMS) has been developed to improve the focusing of brain excitation, and to stimulate or scan the different pa m rts of the brain simultaneously [2]. In this paper, we present a designed mTMS system. By employing a 3D human head model and impedance method, we calculate the electric eld distribution in the human head.

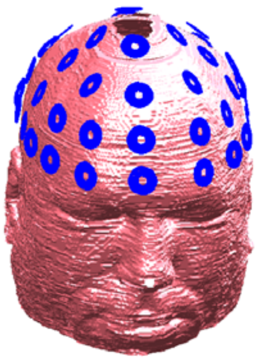

Figure 3. Designed multichannell TMS applicator

4. Source localisation

Particle Swarm Optimization (PSO) was developed in 1995 by Kenedy and Eberhart [3], this new stochastic evolutionary computation technique is based on collective behaviours and it has been found to be extremely effective in solving a wide range of engineering problems.

We have used this method finger movement classification are focused on a few central electrodes locations. It is because these electrodes are closed to the left and right-hand primary motor cortex, concerned with the initiation of voluntary movement and the somatosensory cortex, which receives tactile information from the body

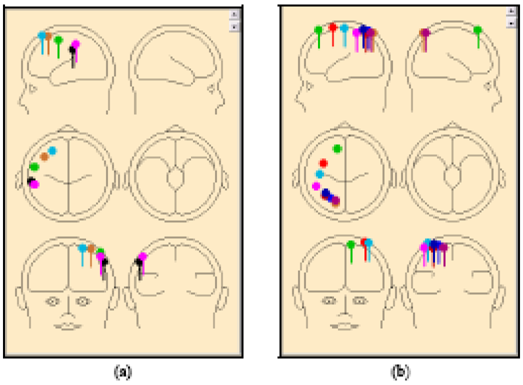

Figure 5 Right Source Location (a) 5 samples around EEG minimum peak
(b) 10 samples around EEG maximum peak.

Our results have shown that, Particle Swarm optimization can be used for optimizing the EEG inverse problem. In general, the magnitude of the localization error caused by using a spherical head model varies with the location of the source in the brain and the sphere parameters. However, PSO effectively finds the dipole localization with millimetres errors.

5. Microwave tomography

Our earlier iterative electromagnetic time-domain inversion algorithm [4] has been developed and modified to include a priori data of the shape and dielectric properties of an object being imaged. The algorithm is based on solving the regular and the adjoint Maxwell's equations in order to compute gradients, which are used to update the dielectric profile with the conjugate-gradient method. As an alternative a global optimisation algorithm, the particle swarm optimisation method, has also been investigated.

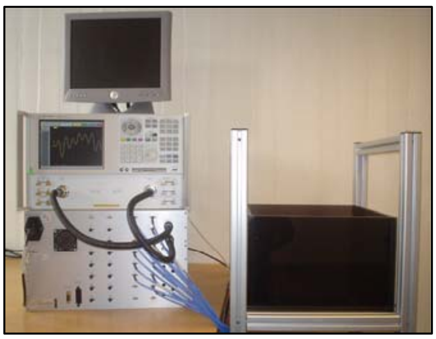

Figure 6. The microwave tomography prototype system

The results show that by exploiting a priori dielectric data in this way a significant improvement in the resolving ability can be obtained. Finally Tikonov and edge preserving regularisation has been investigated and a modified regularisation scheme, supporting the a priori data is suggested. The algorithms have been tested with the microwave tomography prototype system shown in Figure 6.

6. Microwave hyperthermia

Recently clinical trials have shown a significant advantage of using hyperthermia combined with radiotherapy and/or chemotherapy in the treatment of solid tumors [5-7]. A new exciting method to focus the radiation has been developed that promises to take microwave hyperthermia to the next level [8]. The first experimental results with this prototype will be presented.

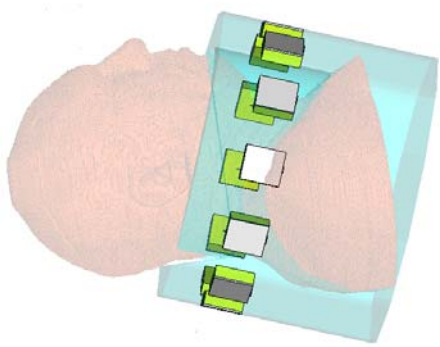

Figure 7. The Near field beamfoming hyperthermia design

7. References

[1] S. Ueno, T. Tashiro, and K. Harada, .Localized stimulation of neural tissues in the brain by means of a paired con_guration of time-varying magnetic _elds., J. Appl. Phys., Vol. 64, no. 10, pp. 5862-5864, 1988.

[2] J. Ruohonen, R. J. Llmoniemi, .Focusing and targeting of magnetic brain Stimulation using multiple coil., Medical _ Biological Engineering Computing, pp. 297-301, May, 1998.

[3] J.Kennedy and R.C Eberhart, “Particle swarm optimization”, in Proc. IEEE Conf. Neural Networks IV, Piscataway, NJ, 1995.

[4] A. Fhager, P Hashemzadeh, M Persson, “Reconstruction Quality and Spectral Content of an Electromagnetic Time-Domain Inversion Algorithm”. *IEEE Transactions on Biomedical Engineering*, **vol. 53**, no 8, pp. 1594 -1604, 2006.

[5] J. Van der Zee, D. Gonz’ales Gonz’ales, G. C. Van Rhoon et al., ¨Comparison of radiotherapy alone with radiotherapy plus hyperthermia in locally advanced pelvic tumors: a prospective, randomised, multicentre trial¨, Lancet, vol. 355, 1119-1125, 2000.

[6] R. Colombo, L.F. Da Pozzo, A. Salonia, P. Rigatti, et al., "Multicentric Study Comparing Intravesical Chemotherapy Alone and With Local Microwave Hyperthermia for Prophylaxis of Recurrence of Superficial Transitional Cell Carcinoma.", J Clin Oncol., vol. 21, 4270-4276, 2003.

[7] E.L. Jones, J.R. Oleson, L.R. Prosnitz, T.V. Samulski, Z. Vujaskovic, D. Yu, L.L. Sanders, M.W. Dewhirst et al., "Randomized Trial of Hyperthermia and Radiation for Superficial Tumors", J Clin Oncol., vol. 23, 3079-3085, 2005.

[8] H. Trefn´a, M. Persson, “Hyperthermia treatment of deep seated tumors using time reversal cavities”, *ESHO 2006 - Book of Abstracts*. Berlin, Germany, 24-27, 2006.