Strategies for Brain Sources and Tissues Properties Identification from EEG/MEG and EIT Signals

Ida M.V. Caminiti (*), Fabrizio Ferraioli (**), Alessandro Formisano (*), Raffaele Martone (*)

(*) Seconda Univ. degli Studi di Napoli, Dip. di Ing. dell'Informazione, Via Roma 29, Aversa CE I-81031, Italy

(**) Ansaldo Energia branch office, Via Nuova Delle Brecce 260, Napoli I-8014, Italy

E-mail: raffaele.martone@unina2.it

Abstract—The estimation of human brain cellular activity from EEG/MEG signals requires a rather accurate knowledge of the living tissues electrical properties. The identification of these properties from joint EEG/MEG measurements as well as from impedance tomography has been thoroughly investigated in literature. In this paper, an assessment of the information content coming from each diagnostics, and their possible interactions, will be presented and discussed.

I. Introduction

Electro-EncephaloGraphy (EEG) and Magneto-EncephaloGraphy (MEG) are becoming important diagnostic tools for the production of real time functional images of human brain activity. In both the imaging techniques, the neural activity is typically modelled as a distribution of impressed currents located in an equivalent conducting material [1], [2]. Of course, the measured values depend on the head tissues properties [1], this dependence being particularly strong for EEG. On the other hand, living tissues are highly complicated, intrinsically anisotropic, structures whose modelling is a non-trivial issue. Any realistic modelling of the process requires then reliable knowledge of *local* tissue properties, that can be obtained either using the EEG/MEG signals themselves [3] or from Electrical Impedance Tomography (EIT) [4]. In the full paper, advantages and drawbacks of tissues properties estimation from EEG/MEG, EIT and/or combined EEG/MEG-EIT data will be discussed.

II. Mathematical formulation

For the sake of exposition, in this digest a suitable number of fixed position current dipoles will be considered as equivalent sources for neural activity, and the head tissues will be modelled as linear conducting materials. The reconstruction of dipoles amplitude from EEG and/or MEG measurements is typically approached by minimizing the error function [1]:

$$\mathcal{E}(\underline{r}_q, \underline{q}, \sigma) = \left\| \underline{\underline{U}}\left(\underline{\underline{G}}\left(\sigma, \underline{r}_q\right)\underline{q} - \underline{M}\right)\right\|^2 + \alpha^2 \left\| \underline{\underline{W}}\underline{q}\right\|^2 \tag{1}$$

where $\underline{\underline{G}}$ is the gain matrix, $\underline{M}$ the measurements array, $\underline{q}$ is an array containing the dipoles moment components, $\underline{r}_q$ is the array of (known) dipoles position, σ is the (estimated) conductivity map, $\underline{\underline{W}}$ and $\underline{\underline{U}}$ are suitable pre-conditioning matrices, and α is the regularization parameter. The underlying model, allowing computation of $\underline{\underline{G}}$, is stationary conduction. If tissues properties are unknown, the elements of $\underline{\underline{G}}$ become also unknown, making the problem non-linear. For EIT the formulation is similar, but $\underline{\underline{G}}$ is estimated by applying known patterns of external sources.

Formulation (1) suffers from well-known limitations of the underlying model (e.g. if the model is current driven, and a single homogeneous conductivity is assumed, it is not possible to isolate source amplitude and conductivity by voltage measurements only), and the integration of different measurements reveals necessary if conductivity values are not reliably known. Comparison and possible integration of different conductivity estimates are not investigated in literature to the authors' knowledge, and are the aim of this paper.

III. Preliminary results and discussion

The impact of EIT and MEG on the estimation of sources and tissues properties from scalp voltages in a very simple case will be discussed here. The conductivity of a homogenous sphere modelling the head and the amplitude of a single tangential current dipole are considered as unknowns. Contours of (1) are reported in Fig. 1 for pure EEG measurements. The diagonal dashed line represents the solutions locus of the considered inverse problem. If, more realistically, uncertain data are considered, the solution from a line turns into a band. Use of MEG measurement in this simple, highly simplified, example, allows to get a single solution. Similarly, realistic EIT estimate of the conductivity gives a second possibility to resolve ambiguity. Uncertainties make the two solutions not to coincide. This issues will be thoroughly investigated in the full paper using more realistic models of head, and eventually more dipole sources.

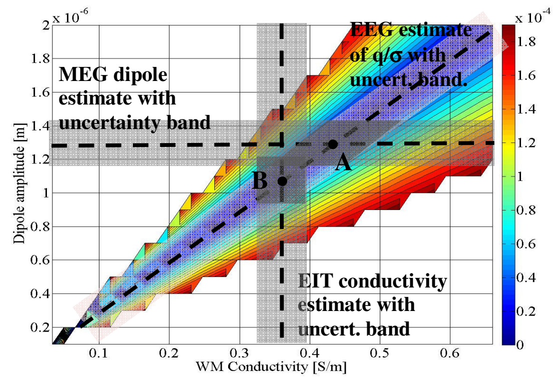

Fig. 1. Estimation of dipole moment q and brain white matter conductivity σ by coupling EEG with MEG (point A) and EEG with EIT (point B).

IV. References

[1] S. Baillet, J. C. Mosher, and R. M. Leahy, "Electromagnetic brain mapping", *IEEE Sig. Proc. Mag.*, Vol. 18, No. 6, pp. 14-30, 2001.

[2] R. H. Bayford, "Bioimpedance Tomography (Electrical Impedance Tomography)", *Annu. Rev. Biomed. Eng.*, Vol. 8, pp. 63-91, 2006.

[3] H. M. Huizenga, T. L. van Zuijen, D. J. Heslenfeld, and P. C. M. Molenaar, "Simultaneous MEG and EEG source analysis", *Phys. Med. Biol.*, Vol. 46, pp. 1737-1751, 2001.

[4] S. I. Gonçalves et al., "In Vivo Measurement of the Brain and Skull Resistivities Using an EIT-Based Method and Realistic Models for the Head", *IEEE Trans. on Biom. Eng.*, Vol. 50, No. 6, pp. 754-767, 2003.

978-1-4244-7062-4/10/$26.00 ©2010 IEEE