MEG: New Techniques

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Introduction

The development of large array neuromagnetometers has provided a new tool to initiate the clinical validation of the neuromagnetic method. Indeed, systems permitting to map the magnetic activity over a relatively large portion of the scalp (with sensors measuring the field perpendicularly to a spherical surface covering an area 13 to 16 cm in diameter) are already available in several experimental facilities. Some of them are commercial instruments, whereas many others are laboratory prototypes featuring even more challenging performances. Few national projects have been initiated in Europe, Canada and Japan, which will make available "whole-head" systems in the next future. These systems will provide the ideal tool to perform the above mentioned clinical validation at specific sites devoted to integration of information coming from various imaging modalities. In the present paper we will briefly describe the state of the art of neuromagnetic instrumentation and the development that are expected for the near future. SUCCESSIVELY we will give some examples of recent studies performed in the Rome neuromagnetic laboratory at the Istituto di Elettronica dello Stato Solido of C.N.R. mostly using the available 28-channel biomagnetic hybrid system. Special emphasis will be given on the benefits that are likely to be achieved in the clinical field.

Instrumentation

To understand MEG and the new techniques related to MEG it is important to discuss first about the presently available biomagnetic instruments and the possible evolution of this field. In fact, biomagnetic instrumentation is rapidly changing and this field is greatly affecting the results obtained both in clinical and fundamental studies. Linked to this "hardware" problem there is also a "software" one. As the evolution of biomagnetic instrumentation is providing more and more powerful systems, software is becoming more and more essential to extract all available information from the data. For instance with software techniques it is possible to obtain "equivalent gradiometers" of high order, or, in other words, we can simulate second or third order gradiometer with data coming from a first order one.

Today the available multichannel systems permit to map the magnetic activity over a relatively large portion of the scalp. However, this is not always sufficient to record all possible information about the underlying electrical activity. This difficulty is particularly evident in clinical studies and primarily in studying patients affected by partial and generalized epilepsy, where the source location is not known in advance with sufficient precision, and the active region of the cortex may be too wide to be approximated by a point source like the current dipole source.

Nowadays there are several multichannel instruments specifically designed for MEG. All of them operate in a magnetically shielded rooms. However this is not a serious drawback since the dimensions of these rooms are adequate and the comfort is satisfactory. The first commercial multichannel biomagnetic system was introduced by BTI several years ago. Today the most advanced device produced by this company is a 37 channel system (Biomagnetic Technologies Inc., 9729 Pacific Heights Blvd., San Diego, CA 92121), with first order gradiometer of 20 mm diameter and 50 mm baseline. The

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pickup coils are positioned on a spherical surface of 120 mm radius, oriented normally to the sphere, and the total measuring area is about 160 mm^2. Noise level is ~10 fT (Hz)^{-1} above few Hz.

A different instrument is available from Siemens (Hoenig et al. 1991). This system features 37 first order axial gradiometers inside a circular area of 190 mm radius. The pick-up coils have an hexagonal shape of 6 cm^2 and a baseline of 70 mm. The measuring array is flat and therefore is mainly intended for cardiological measurements, but at least for measurements of the magnetic field over the temporal region of the brain. The noise level of this system is <10 fT (Hz)^{-1} above 10 Hz.

Other companies like CTF in Canada (CTF Systems Inc. 15-1750 McLean Av., Port Coquitlam, British Columbia, CANADA V3C 1M9) are working on neuromagnetometers covering the whole head with 64 axial first order gradiometers. This system will be able to operate in unshielded environment using software second or third order gradiometers.

Other biomagnetic systems are being used in several laboratories all over the world. At the Helsinki University of Technology a 24 channel system in operation (Ahonen et al. 1991). This device has 12 two-planar gradiometer units measuring dBz/dx and dBz/dy in 12 different places on a spherical cap of 125 mm diameter. The area of the pick-up loops is 3.7 cm^2 and the baseline is 13 mm. This system is operating inside a heavily shielded room where exhibits a noise of 3-5 fT (cm)^{-1} (Hz)^{-1}. Recently a new system covering the whole head with 122 channels has been announced (Ilmoniemi, this volume). A company, Neuromag Ltd., will commercialize this system.

At the Istituto di Elettronica dello Stato Solido of C.N.R. we have developed a 28 channel biomagnetic hybrid system (Foglietti et al. 1991; Torrioli et al. 1992). This system operates in a shielded environment, and features 28 first order gradiometers arranged on a spherical surface with radius of 135 mm. Out of the 28 channels, 16 are axial gradiometers with 18 mm coil diameter and 85 mm baseline, 12 are planar with 10 mm coil diameter and 15 mm baseline (see figure 1). The total area covered by the sensor is about 180 cm^2. The dc-SQUID used are fabricated at IBM laboratories. A simple low-cost electronic system has been manufactured for biomagnetic measurements operating in the conventional flux locked loop configuration. The noise of the axial gradiometers is 5-7 fT (Hz)^{-1} and for the planar ones is 6-8 fT (cm)^{-1} (Hz)^{-1} above 2 Hz. Presently a "class 100 channel system" covering the whole head is under development in the frame of a national project sponsored by the National Research Council (C.N.R.). Another whole head system will be installed at the recently established Institute for Advanced Biomedical Technologies (ITAB) of the University of Chieti, and will be devoted to basic and clinical research. Data originating from this system will be directly compared and integrated with information coming from MRI, CT scan, and SPECT, which will be available in the same facility.

Examples of MEG studies

In this paper we will present some results obtained in the ongoing studies at the IESS-CNR mainly accomplished with the 28 channel system previously described. The first example concerns an investigation on the functional organization of the somatosensory cortex, the other two are rather linked to validation of the clinical capability of the method.

Effect of stimulus intensity on source parameters

It has been repeatedly observed in evoked potentials measurements under median nerve electrical stimulation at the wrist that the cortical response features significant modifications with respect to variation of stimulus intensity (Bodis-Wollner (ed)). A similar effect was recently studied by Peresson et al. (1992) for the N20m component.

To investigate this issue seven fully informed normal subjects were examined. Somatosensory Evoked Fields (SEFs) elicited by left median nerve stimulation were recorded over the right hemisphere together with muscle action potential, nerve compound potential and scalp electric potential. Stimulation consisted of 0.1 ms pulses delivered at 302 ms interval and with three different intensities: a) level A minimum level to obtain a clear sensitive perception; b) level B standard stimulus inten-