DC-MEG Studies: Development of Techniques for Resolving DC Fields

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Introduction

Long duration magnetic field changes (DC) [1] in MEG may occur as a result of migraine [2], anoxia [3], epilepsy, closed head injury etc. These Field changes are easily masked by changes due to artifacts. It is therefore useful to separate the DC field changes of interest, i.e; arising from physiological phenomena, from those arising from external sources. The ability to measure these DC phenomena may lead to improvements in diagnosis and prognosis for treatment and recovery. With MEG we have successively measured DC field changes over periods of minutes to one hour. For these studies no absolute DC level can be established but shifts in (DC) levels over time can be recorded. However, we are presently developing new techniques to record changes of DC magnetic field amplitude which occur over a period of days or weeks. The problems that must be addressed to obtain meaningful DC measurements include arbitrary neuromagnetometer baseline, non-uniform residual magnetic field within the shielded room and the need to accurately reposition the subjects and control the distance between the cortex and sensor array. In this study, we describe results we have obtained for both experimental DC source models and actual DC field measurements recorded on human subjects on three consecutive days.

METHODS

A study using a glass dipole head model, was carried out. Twenty second epochs of continuos MEG data were collected from each of the seven placements of a seven channel BTi model 607 magnetometer. In each run, 2 seconds of baseline data were collected before slowly lowering the head away from the magnetometer probe over a period of 16 seconds. An additional 2 seconds of data were collected at this new level.

However in order to use this lowering technique in human studies it is necessary to separate the DC field due to the source of interest from the DC fields from other sources in the body. A second study using the dipole head model with an interfering DC source was carried out. The interfering source was a current loop wrapped around the glass head. Twenty second epochs of continuous MEG data were collected as described in the first study. In the first run both the dipole and the external wire were energized; the second run was carried out with only the dipole energized. The third run had only the external wire energized.

Based on the technique of lowering described above, a technique to measure the changes in DC fields from human subjects with changing distance from the sensor array, was developed in this study. The position of the magnetometer probe with respect to the shielded room was fixed, the orientation of the hexagonal array of sensors was also fixed. The wooden platform on which the subject lay was fixed with respect to the room and with respect to the magnetometer probe. The subject lay on a wooden platform with his/her head in the head holder, which was fixed to the platform. The magnetometer probe was aligned such that it just touched the subject's head and the vertical axis was the Z-axis. This entire setup was kept the same throughout the study and through all three days of the study. For description of the apparatus refer to Fig. 1.

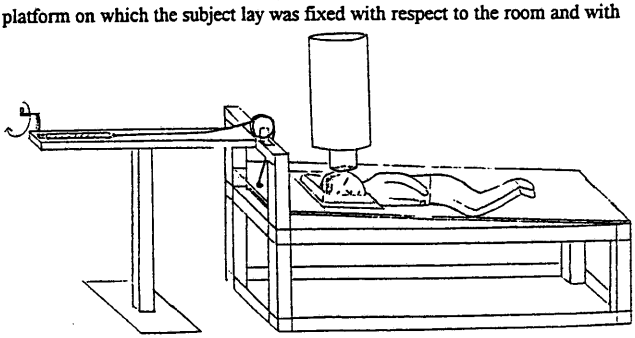

Fig. 1 The experimental apparatus.

Ten seconds of data were collected at this initial position, then the subject was slowly lowered away from the probe through a distance of 1.7 cm. Measurements were made after each step but not during the process of lowering. This lowering was done in seven equal steps. At each of these seven levels, ten seconds of data were collected. The subject was then raised all the up to the initial position, and the study repeated. The exact position of the subject was established using BTi's probe position indicator program A total of three successive runs of were carried out. This set of three runs was repeated thrice over three days, one set each day. Another study with no subject under the probe was carried out each day. Data from this study was used as the noise data for that day.

DATA ANALYSIS and RESULTS

The data were digitized using an HP 694A multiprogrammer. All the data were sampled at 130Hz and the high and low pass filters were set at 0 and 50 Hz respectively.

1) A dipole fitting algorithm was applied to the data from the first study with the glass dipole head at a latency point during or after the drop, and the model accepted only for dipole correlations greater than 0.91. The total drop was 3 cm. The shift in the DC level due to the drop was 15 pT(Fig. 2) at the field maximum. There was no discernible shift in the DC level when the head was lowered from the probe without the dipole being energized.

2) Data from the 3 runs of the second study with the glass dipole head were analyzed and it was seen that the DC shift due to the dipole could be extracted form the total shift (dipole+external wire) by a simple subtraction of the signal from the wire from the total shift (Fig. 3). This result validates our procedure for resolving the DC interference from the dipole source.

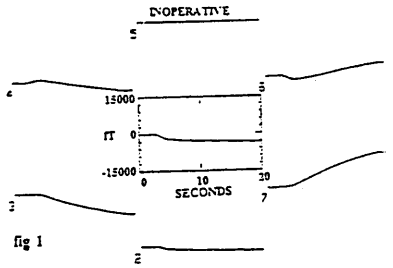

Fig. 2 The above figure shows the shift in the DC level (15pT), due to the lowering of the glass dipole head.

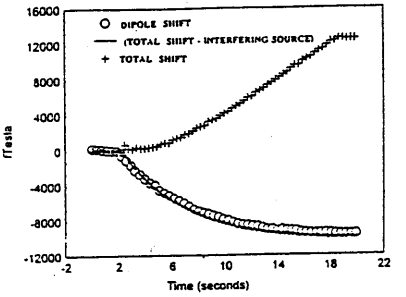

Fig. 3 The above figure shows the shift due to the dipole extracted from the total shift.

3) Data from the human studies were time averaged and decimated. The change in the DC magnetic field amplitude with distance moved is nearly linear. Therefore, we use the average change of the magnetic field amplitude with distance to quantify the DC field. The average change computed for one run was compared to the average change computed for each of the other runs of the same day, to asses run to run repeatability. Figs. 4,5,6 demonstrate run to run variation can be controlled by run averaging with our present positioning and movement control system. The DC field change per cm distance change for three successive days is plotted.(Fig. 7). The DC field amplitudes of the first and third day are nearly identical. Factors contributing to the different DC amplitudes recorded on the second day include alignment inaccuracies of the sensor array relative to the subject and the room plus physiological change.

4) The time averaged amplitude of the fast activity (AC) components of the spontaneous MEG data is also attenuated as the distance from the sensor array to cortex is increased. The amplitude of this activity is also expected to be altered by pathology. In addition, the amplitude of the fast activity and the DC amplitudes may be found to be correlated. Therefore, we have developed a mathematical model of the time averaged AC amplitude which assumes uniform cortical activity. Assuming uniform cortical activity change in amplitude with distance is found to be :

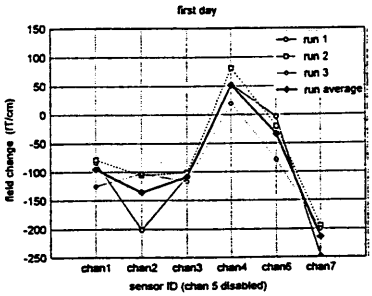

Fig. 4 First day's DC field amplitude measurements for each run and the average of these runs.

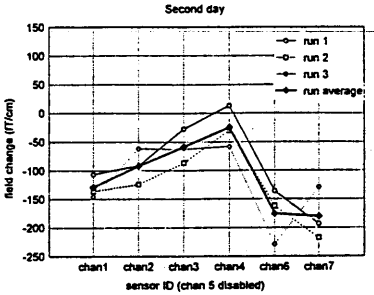

Fig. 5 Second day's DC field amplitude measurements for each run and the average of these runs.

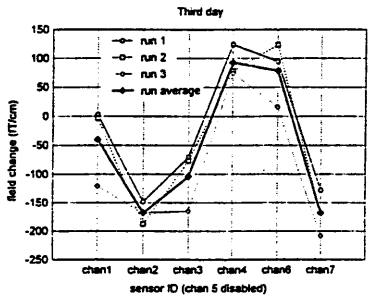

Fig. 6 Third day's DC field amplitude measurements for each run and the average of these runs.

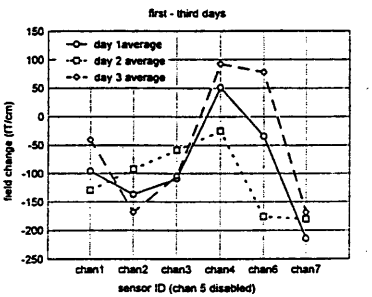

Fig. 7 The DC field change per cm distance change for three consecutive days is shown.

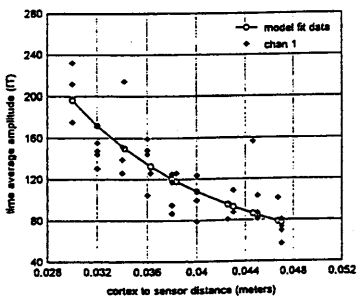

Fig. 8 The time averaged amplitude of the fast activity components of MEG data is attenuated as sensor - cortex distance increases. The solid line fits the equation used in the result and ρ was was found to be 2.1.

time averaged amplitude = constant / (distance to cortex)$^{\rho}$

For the data shown in Fig. 8 the solid line fits the above equation with ρ equal to 2.1. For the complete sensor array in this run, ρ was found to be 1.89 ± 0.15.

DISCUSSION

The technique developed in this study greatly reduces the time required to complete an entire study. Each run is completed in less than two minutes, hence subject fatigue is minimal. Also, since the total time that the subject is monitored is less than ten minutes, the subjects state of arousal remains nearly the same throughout the study. This eliminates the error introduced in the interpretation of the results due to comparison of data collected during two different states of arousal.

A range for variation in subjects with no pathology has to be established. Once this is established, further studies with subjects who have had strokes, closed head injury etc have to be performed. Data from these subjects could then be compared to data from the controls. Also the day to day variation in subjects with pathology could indicate changes in the physiology or function of the brain. It could also indicate change in function after surgery, indicating perhaps healing of the injured tissue.

The problems mentioned in the introduction have to be addressed in order to get any meaningful results with the technique we have developed. Reducing alignment problems of the sensor array is presently our greatest priority. The position of the subject with respect to the probe has to be kept the same in order to be able to compare any two sets of data and to be able to establish that the changes that we might observe have a physiological basis.

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