MAR14-2013-020108

Abstract for an Invited Paper
for the MAR14 Meeting of
the American Physical Society

Magnetoencephalography: From first steps to clinical applications[1]

RISTO ILMONIEMI, Aalto University

Magnetoencephalography (MEG), the study of femtotesla-range magnetic fields produced by neuronal currents in the brain, originated in the 1960's. After Baule and McFee's (Am Heart J 66:95-6,1963) measurement of the cardiac magnetic field using induction-coil sensors, Cohen (Science 16:784-6, 1968) used a similar multi-turn coil to detect the brain's alpha rhythm. The introduction of the superconducting quantum interference device (SQUID) by Zimmerman et al. (J Appl Phys 41: 1572-80) improved the sensitivity of magnetic sensing by several orders of magnitude, making MEG practical. The SQUID enabled the unaveraged recording of spontaneous brain rhythms (D. Cohen, Science 175:664-6, 1972) as well as evoked magnetic fields (Brenner et al., Science 190:480-2, 1975; Teyler et al., Life Sci 17:683-91, 1975). Subsequently, a large number of evoked-field variants were demonstrated. The main benefit of MEG is its ability to locate electrical activity in the brain at high temporal resolution. For practical work, we need large arrays of highly sensitive SQUIDs; such arrays were first built in the 1990's (Knuutila et al., IEEE Trans Magn 29:3315-20, 1993). While the intrinsic spatial accuracy of locating sources with well-calibrated large sensor arrays is better than one millimeter, uncertainties in determining the location and geometry of the cortex with respect to the array may lead to source-location errors of 5–10 mm or more. These errors could be reduced to 1 mm if one could obtain the structural image of the brain with the same sensors that are used for MEG and if the conductivity geometry of the head would be accurately known. This may indeed be possible if MRI is recorded with SQUIDs (McDermott et al., PNAS 21:7857-61, 2004) concurrently with MEG (Zotev et al., J Magn Reson 194:115-20, 2008), especially if large arrays are developed (Vesanen et al., Magn Reson Med 69:1795-1804, 2013); the conductivity distribution of the head might be possible to determine with current-density imaging (Nieminen et al. Magn Reson Imaging, 2013). MEG has established itself as a standard tool in human neuroscience (Hamalainen et al., Rev Mod Phys 65:413-97, 1993). It is used increasingly in clinical applications such as in locating motor or language areas prior to brain surgery or in determining characteristics of epileptic activity of patients.

[1]Support from the Academy of Finland is acknowledged.