EFFECT OF SKULL RESISTIVITY ON THE RELATIVE SENSITIVITY DISTRIBUTIONS OF EEG AND MEG MEASUREMENTS

J. A. Malmivuo[1], V. Suihko[2]
[1]Ragnar Granit Institute, Tampere University of Technology, Tampere, Finland
[2]Department of Clinical Neurophysiology, Seinäjoki Central Hospital, Seinäjoki, Finland

Abstract-**We have previously published calculations which show that, contrary to what has been believed, despite the high resistivity of the skull the spatial sensitivity of magneto-encephalography, MEG, is no better than that of electro-encephalography, EEG. The results were based on the widely used Rush-Driscoll head model, where skull resistivity is considered to be 80 times that of the brain and the scalp.**

Recent research indicated that the skull resistivity is only about 15 times that of the brain and scalp. Calculations of EEG sensitivity distributions with this value show that EEG has considerably better spatial resolution than MEG. Since clinical recordings are not in conflict with such a result, the conclusion can be considered reliable. The finding supports use of high-resolution EEG as research and clinical tool in recording the electric activity of the brain.

Keywords - **Bioelectromagnetism, electroencephalography, magnetoencephalography**

I. INTRODUCTION

The electric activity of the brain generates both electric and magnetic fields, detected as electroencephalography, EEG, and magnetoencephalography, MEG. Both of these techniques are nowadays used as research and clinical tools. For the benefit of the brain research it is important to discuss about the relative merits of these techniques. In this discussion there exist several issues, theoretical and technical. One of these issues is the spatial resolution.

We have previously demonstrated with calculations with the Rush-Driscoll model that the spatial resolution of the axial gradiometer is an order of magnitude poorer than that of a bipolar EEG measurement. The spatial resolution of a planar gradiometer in the Rush-Driscoll model is about the same order as that of the bipolar EEG. [1 - 4]

It has recently been demonstrated with several different approaches that the earlier conception of the high resistivity of the skull is overestimated and that the correct ratio between the resistivity of the skull and that of the brain and scalp tissues is 15/1 [5]. We recalculated the most central results of our previous study with this resistivity ratio to obtain more reliable information on the relative spatial resolutions of the EEG and MEG.

II. METHODS

To investigate the EEG and MEG detectors' ability to concentrate their measurement sensitivity we use the concept half-sensitivity volume (HSV). The HSV is the volume of the source region in which the magnitude of the detector's sensitivity is more than one half of its maximum value in the source region [1]. If a source is homogeneously distributed, the smaller the HSV is, the smaller is the region from which the detector's signal originates.

In comparing the EEG and MEG detectors' merits the criterion has usually been either their accuracy in localizing a source dipole or in differentiating between two nearby dipoles. In a clinical measurement, however, a neurologist is interested in measuring the electric activity of brain tissue from a limited region. That is a volume source, not a discrete dipole. These are, of course, mathematically related concepts.

We compared the spatial resolution of EEG and MEG using the concept of half-sensitivity volume (HSV). This concept has been described in detail elsewhere [3]. For EEG the HSV was calculated for bipolar and three-electrode leads with point electrodes as a function of electrode distance. For MEG the HSV was similarly calculated for a planar gradiometer as a function of baseline. The radii of the MEG coils were 10 mm and their distance from the scalp 20 mm. For the head we used the Rush-Driscoll model with concentric spheres of 80 mm, 85 mm and 92 mm radii for the outer surfaces of brain, skull and scalp, respectively. For the resistivities of these tissues, however, we used the relative values 1/15/1. The earlier results with relative skull resistivities of 1/80/1 and 1/100/1 are also given. The results are thus comparable with those of our earlier paper [3].

III. RESULTS

The HSVs for two and three-electrode EEG and planar gradiometer MEG with brain and scalp/skull resistivity ratios of 1/15, 1/80 and 1/100 as a function of electrode distance and magnetometer baseline are given in Tables I and II and Figure 1. It will be observed that with this new resistivity value for the skull (1/15) the HSV of the EEG is significantly smaller than that of the MEG at all values of electrode distance and magnetometer baseline.

The clinically interesting area at baseline is some 10-20 mm, corresponding to an electrode distance of 128 or 256 electrode High Resolution EEG systems. In this region the HSV of the EEG is about 20 - 45 % smaller than that of the planar gradiometer MEG.

V. CONCLUSION

Our calculations show that, when adopting for scalp, skull and brain the more realistic relative resistivity values of 1/15/1, the HSV is smaller and thus the spatial sensitivity is better for the EEG than for the MEG.

IV. DISCUSSION

The high resistivity of the skull is the main factor affecting the spatial resolution of the EEG. The fact that this has no effect on the spatial resolution of the MEG has been the main reason for the belief that the MEG would provide better spatial resolution than the EEG.

Report Documentation Page

Report Date	Report Type	Dates Covered (from... to)
25 Oct 2001	N/A	-

Title and Subtitle Effect of Skull Resistivity on the Realtive Sensitivity Distributions of EEG and MEG Measurements	**Contract Number**
	Grant Number
	Program Element Number
Author(s)	**Project Number**
	Task Number
	Work Unit Number
Performing Organization Name(s) and Address(es) Tampere University of Technology Ragnar Granit Institute Tampere, Finland	**Performing Organization Report Number**
Sponsoring/Monitoring Agency Name(s) and Address(es) US Army Research, Development & Standardization Group (UK) PSC 802 Box 15 FPO AE 09499-1500	**Sponsor/Monitor's Acronym(s)**
	Sponsor/Monitor's Report Number(s)
Distribution/Availability Statement Approved for public release, distribution unlimited	
Supplementary Notes Papers from 23rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society, October 25-28, 2001, held in Istanbul, Turkey. See also ADM001351 for entire conference on cd-rom.	
Abstract	
Subject Terms	
Report Classification unclassified	**Classification of this page** unclassified
Classification of Abstract unclassified	**Limitation of Abstract** UU
Number of Pages 2	

TABLE I

THE HSV OF BIPOLAR EEG LEADS WITH DIFFERENT SKULL CONDUCTIVITY RATIOS AND HSV OF PLANAR GRADIOMETER MEG LEADS WITH H =20 MM, R = 10 MM. HSVS ARE GIVEN IN [CM³] WITH (1/15) Β, (1/80) Β AND (1/100) Β SKULL CONDUCTIVITIES.

Separation		Bipolar EEG			Planar MEG
degr	mm	(1/15)σ_b	(1/80)σ_b	(1/100)σ_b	
20°	32.0	4.9	8.0	8.5	5.6
10°	16.0	2.1	2.8	3.0	3.8
5°	8.0	1.2	1.5	1.5	3.5
1°	1.6	0.92	1.2	1.2	3.4

TABLE II

THE HSV OF THREE-ELECTRODE EEG LEADS WITH DIFFERENT SKULL CONDUCTIVITY RATIOS. HSVS ARE GIVEN IN [CM³] WITH (1/15) Β, (1/80) Β AND (1/100) Β SKULL CONDUCTIVITIES..

Separation		Three-electrode EEG		
degr	mm	(1/15)σ_b	(1/80)σ_b	(1/100)σ_b
20°	32.0	1.8	2.4	2.6
10°	16.0	0.79	0.67	0.89
5°	8.0	0.4	0.3	0.3
1°	1.6	0.22	0.21	0.22

We have previously shown that even with a relative value of 80/1 skull resistivity, MEG and EEG have about the same spatial resolution. Now the new more realistic resistivity value for the skull yields to a spatial resolution of the EEG which is apparently better than that of the MEG.

ACKNOWLEDGMENT

This work has been supported by the Ragnar Granit Foundation.

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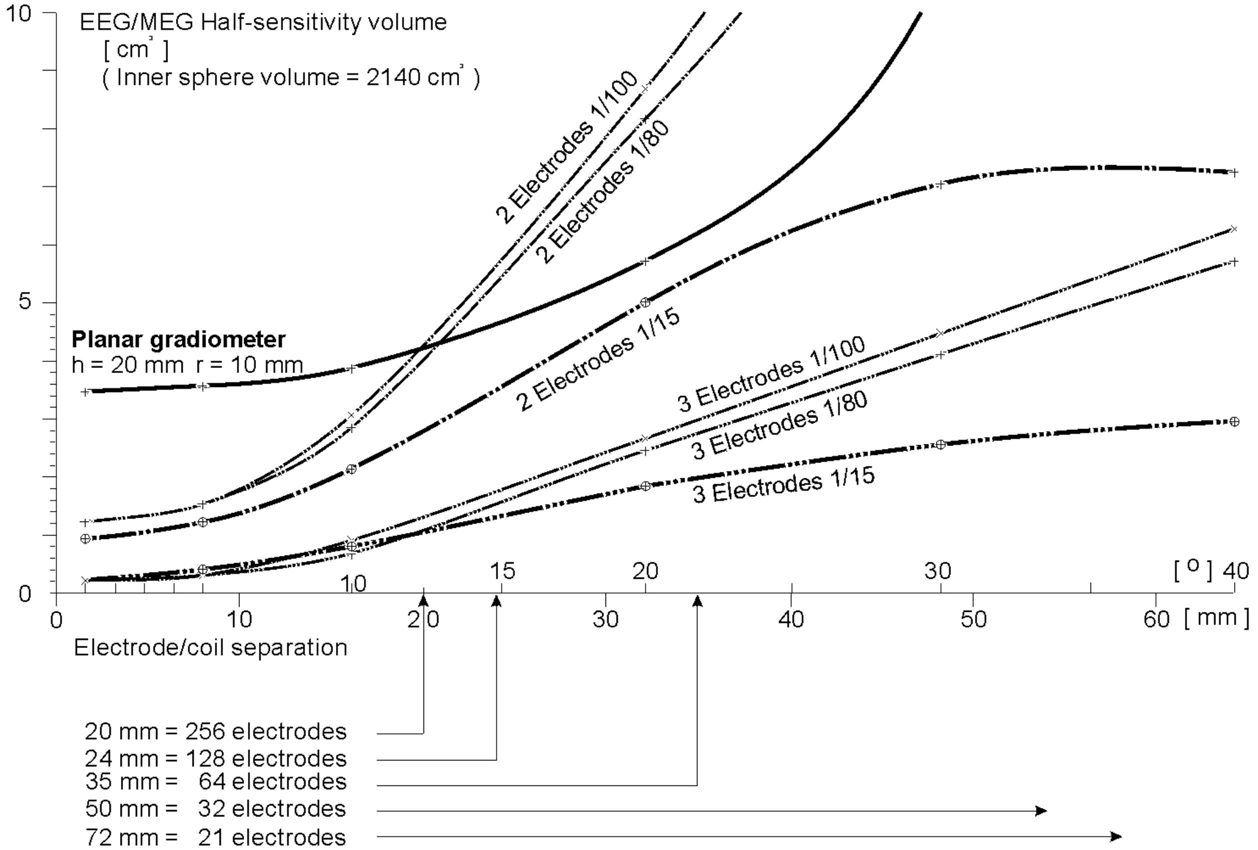

Fig. 1. Half-sensitivity volumes of two- and three-electrode EEG and planar gradiometer MEG as a function of electrode distance/gradiometer baseline. The relative resistivities in EEG are 1/15, 1/80 and 1/100 for brain and scalp/skull. The electrode distances for EEG lead systems with different numbers of leads are also indicated.