Auditory Cortex Signal Detected by Potassium Alkali Vapour Magnetometer

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Introduction

Applying the current dipole model we present the source localization estimation of the auditory evoked magnetic field measured by a noncryogenic potassium vapour atomic magnetometer (PVAM) [1].

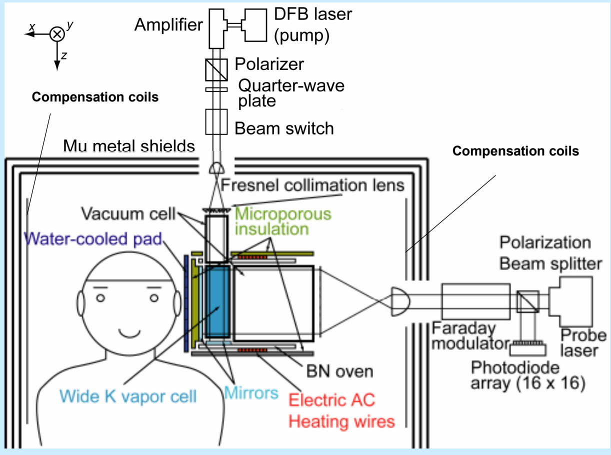

Figure 1: Magnetometer scheme. Probe laser beam is reflected from the mirror on the opposite side of the K cell and projected to the 256 channel photodiode array, arranged in a matrix of 16 by 16 elements. The K cell is placed inside the three layer cylindrical magnetic shield (inner diameter 1 m, length 2.6 m).

A magnetometer scheme is shown in Fig. 1. It was operating in spin-exchange relaxation-free (SERF) regime at low magnetic flux densities and high alkali-metal vapour density [2].
Audio stimulation of short 1 kHz pulse trains has been applied by a pneumatic earphone to the right subject's ear. The interval between each pulse train is varied randomly between 1.3 and 2.0 s to avoid subject's adaptation. The subject's left ear is positioned 5 cm from the potassium cell centre.

Data acquisition and analysis procedure

1.) Compensation of the residual magnetic fields in the volume of the potassium cell by compensation coils inside the inner magnetic shield to assure SERF operation of the magnetometer.

2.) Calibration of the magnetometer channels by applying low frequency magnetic field (50 pT, 10 Hz).

3.) Applying low frequency uniform magnetic field gradient by means of *compensation* coils to get the spatial mapping information from the magnetometer cell to each photodiode position (10 pT/cm, 10 Hz).

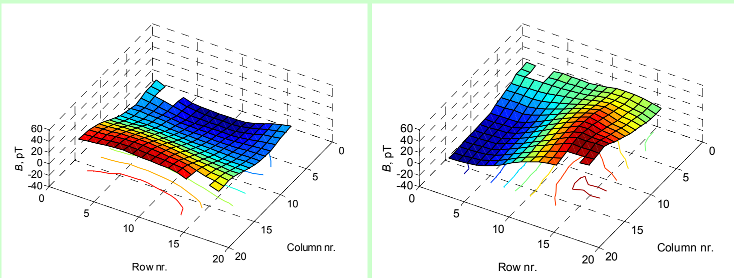

Figure 2: Smoothed measured magnetic field at different photodiode locations with applied uniform magnetic field gradient over the potassium cell. Left: gradient in y direction. Right: gradient in z direction.

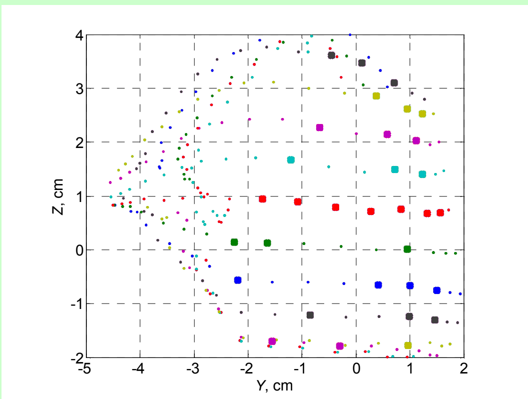

Figure 3: Calculated positions of magnetometer channels. Channels with good signal to noise ratios (channels used in data analysis) are shown with large marks. Some magnetometer channels have uneven spatial field distribution due to optical distortions near the edge of the cell.

4.) Measurement of the auditory evoked magnetic field.

5.) Finding channels with good signal to noise ratio.

6.) Band-pass filtering (2 Hz to 20 Hz) of all magnetometer channels.

7.) Calculation of the gradiometer signals to reject the subject's heart beat signals and disturbances due to mechanical vibrations. One magnetometer was used as a reference and this channel was subtracted from all other channels.

8.) Averaging of the gradiometer signals. (Synchronization signals at time of audio stimulation were used.)

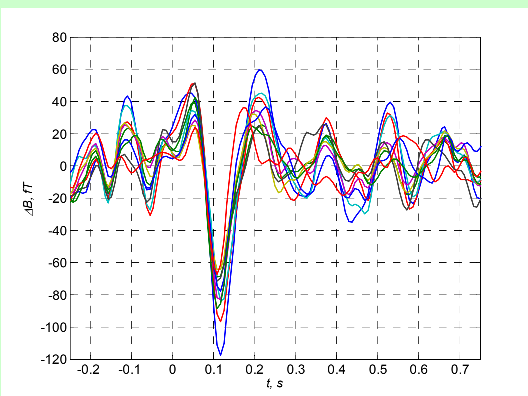

Figure 4: Auditory evoked magnetic gradients obtained with PAVM after averaging. Auditory stimuli was at t = 0 s.

9.) Source localization estimation: We used the homogeneous conducting sphere model with a current dipole inside a sphere and the Minimum Norm Estimation (MNE) for the current distribution on a sphere surface, [3], at *t* = 102 ms after the audio stimulation.

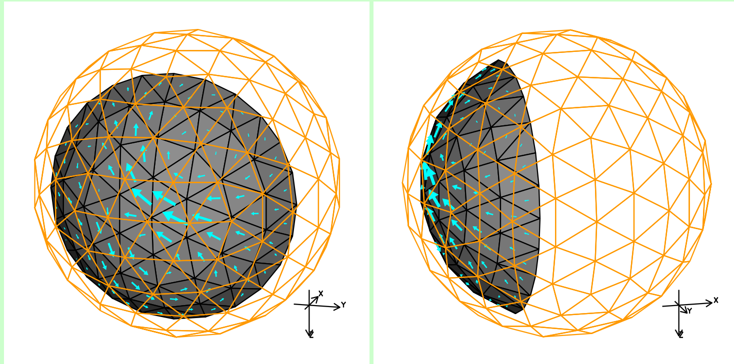

Figure 5: The estimated MNE current distribution in two different views. The head model is a sphere with 9 cm radius, shown with orange open triangles. The reconstruction area of the current distribution is shown with black triangles shaded with grey (spherical cap surface with height hc = 5 cm and radius rc = 8 cm). The estimated current distribution is shown with cyan arrows.

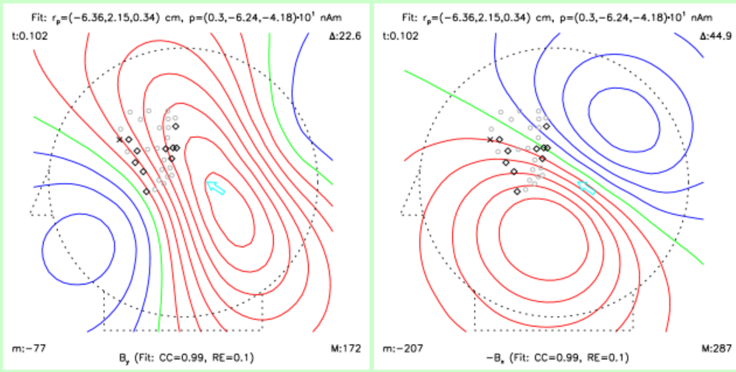

Figure 6: Calculated magnetic contour lines for the By (left) and –Bx (right) component of the current dipole magnetic field. The current dipole has been obtained by fitting signals from ten selected gradiometer channels, defined as difference between the reference (x) and selected channels (◊). Position of the current dipole rp=(-6.36,2.15,0.34) cm relative to the sphere centre.

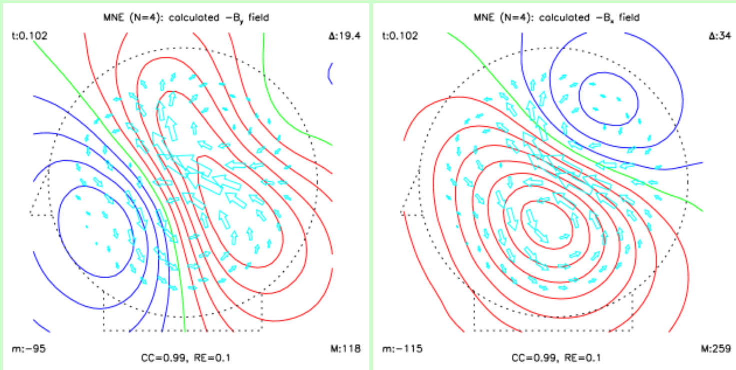

Figure 7: Calculated magnetic contour lines for the estimated current distribution shown in Fig. 5. By (left) and –Bx (right).

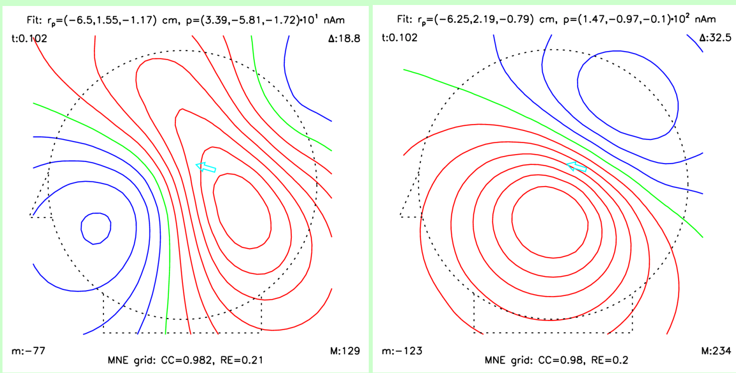

Figure 8: Calculated magnetic contour lines for the current dipole obtained by fitting magnetic field maps shown in Fig. 7. By, rp=(-6.5,1.55,-1.17) cm (left) and –Bx, rp=(-6.25,2.19,-0.79) cm (right).

Conclusion

- Auditory evoked brain activity localization in the auditory cortex was obtained.
- The homogeneous conducting sphere model was used.
- The equivalent current dipole model and MNE for the cortical current distribution was applied.
- The localization of the equivalent current dipole corresponds well with the known position of the auditory evoked brain activity.

Acknowledgments

This work was partly supported by MORS.

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