Detection system of magnetic nanoparticles in biological tissues by Magnetoencephalography

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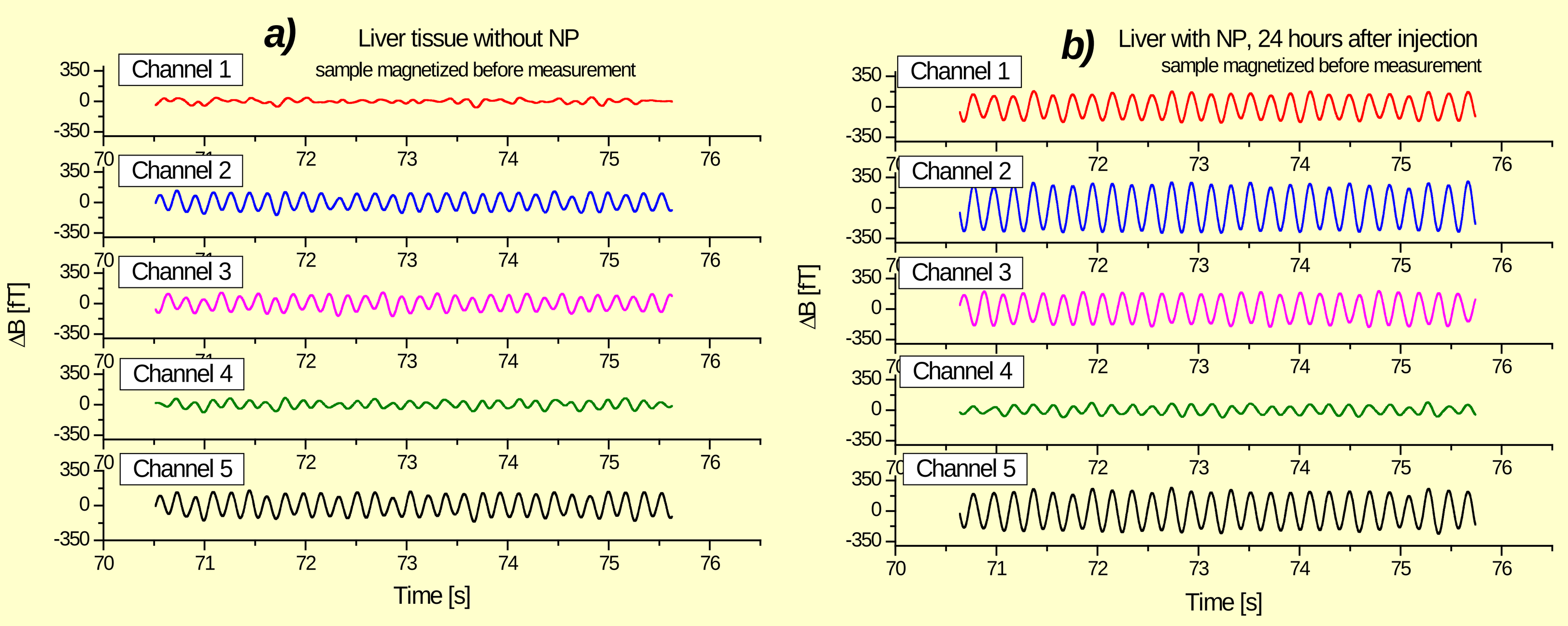
ABSTRACT

Magnetic nanoparticles are useful for a wide range of applications from data storage to medical imaging. Their unique features (controllable size in the nano-scale range, possibility to be coated with biological molecules, response to the application of a magnetic field...) make the development of a variety of medical applications possible, both for diagnosis and therapy [1-3]. On the other hand, Magnetoencephalography (MEG) is a non-invasive functional imaging technique that enables the description of the temporal and spatial patterns of brain activity in resting conditions or related to different basic cognitive processes, by detecting the weak magnetic fields generated by currents in the neurons [4,5]. The detection of the weak magnetic fields depends on gradiometer detection coils coupled to a superconducting quantum interference device (SQUID). However, MEG systems are not currently being used for the detection of MNPs in biological tissues.

A system to newly detect Magnetic Nanoparticles (MNPs) in the brain and in biological tissues will be described. The method uses a commercial Magnetoencephalograph (MEG) and opens new possibilities to extend the use of MEG systems to new applications for both diagnosis and therapy of medical diseases, different from its common use in neurological diagnosis. To test the validity of the system, in this work, we will show its ability to detect MNPs in biological tissues and their possible use in diagnosis of cerebral brain microinjuries.

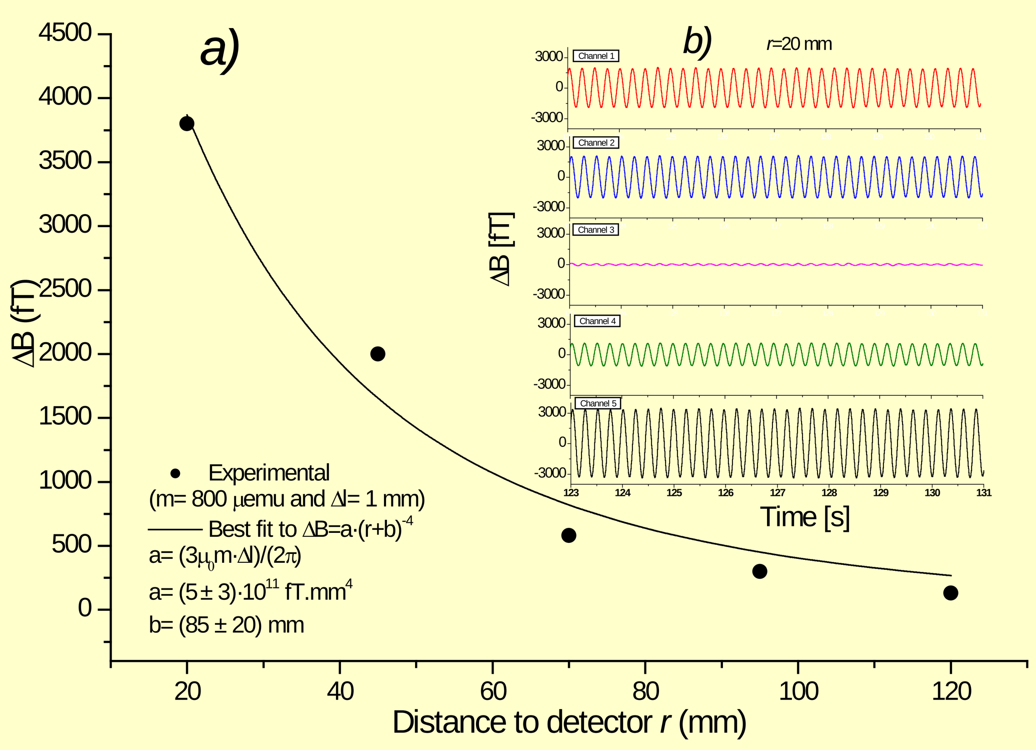
RESULTS

LIVER TISSUE

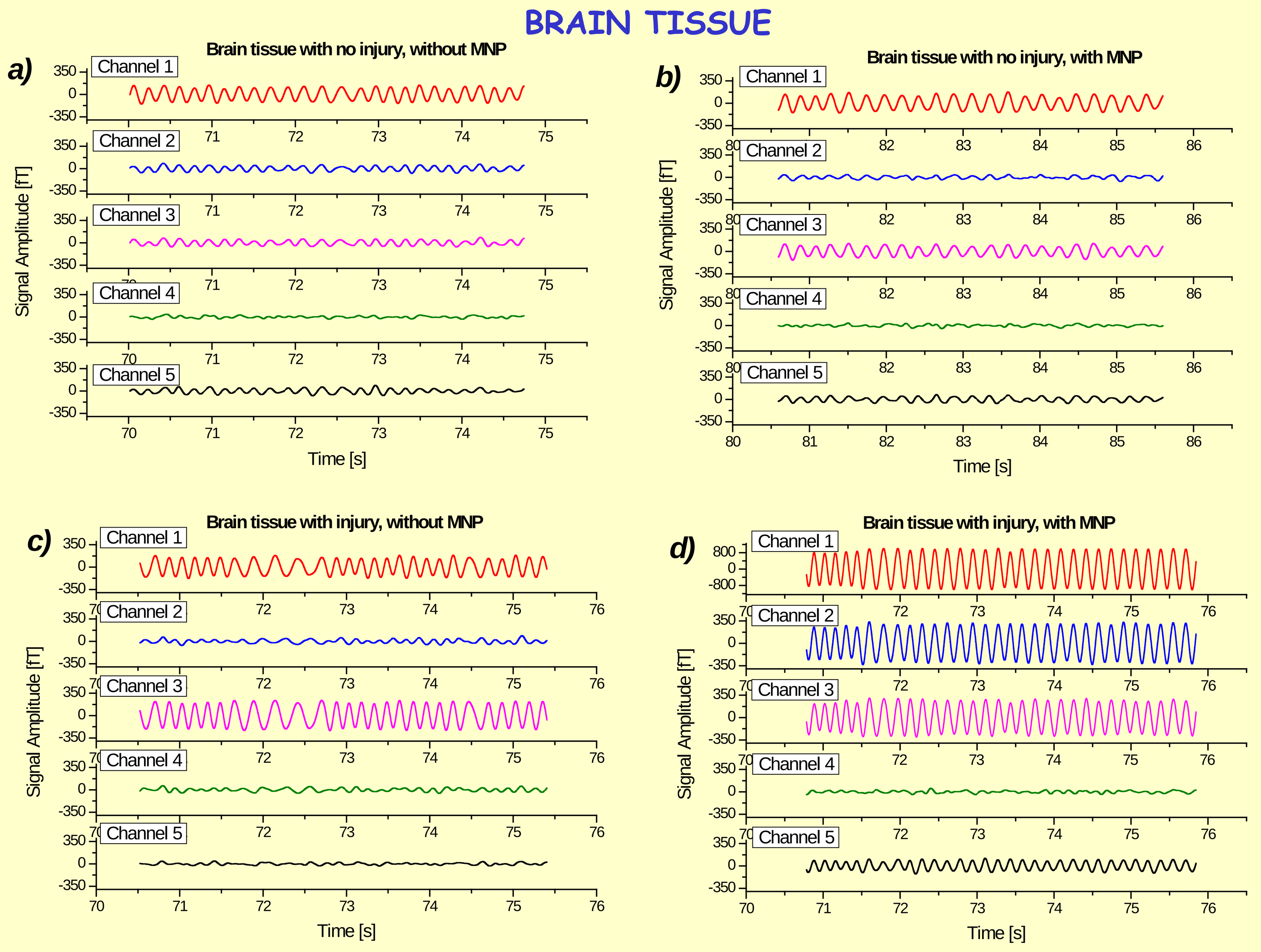


Dependence of the magnetic signal generated by the MNPs, with the distance to the detector

Dots in part **a)** correspond to peak-to-peak value of the signal in Channel 1 averaged during 5 seconds, for a Nickel MNPs sample (20 nm), at different distances from the detector. Part **b)** typically recorded signal from 5 channels of the MEG system, placing the sample at a distance of 20 mm from the base of sensors arrays.



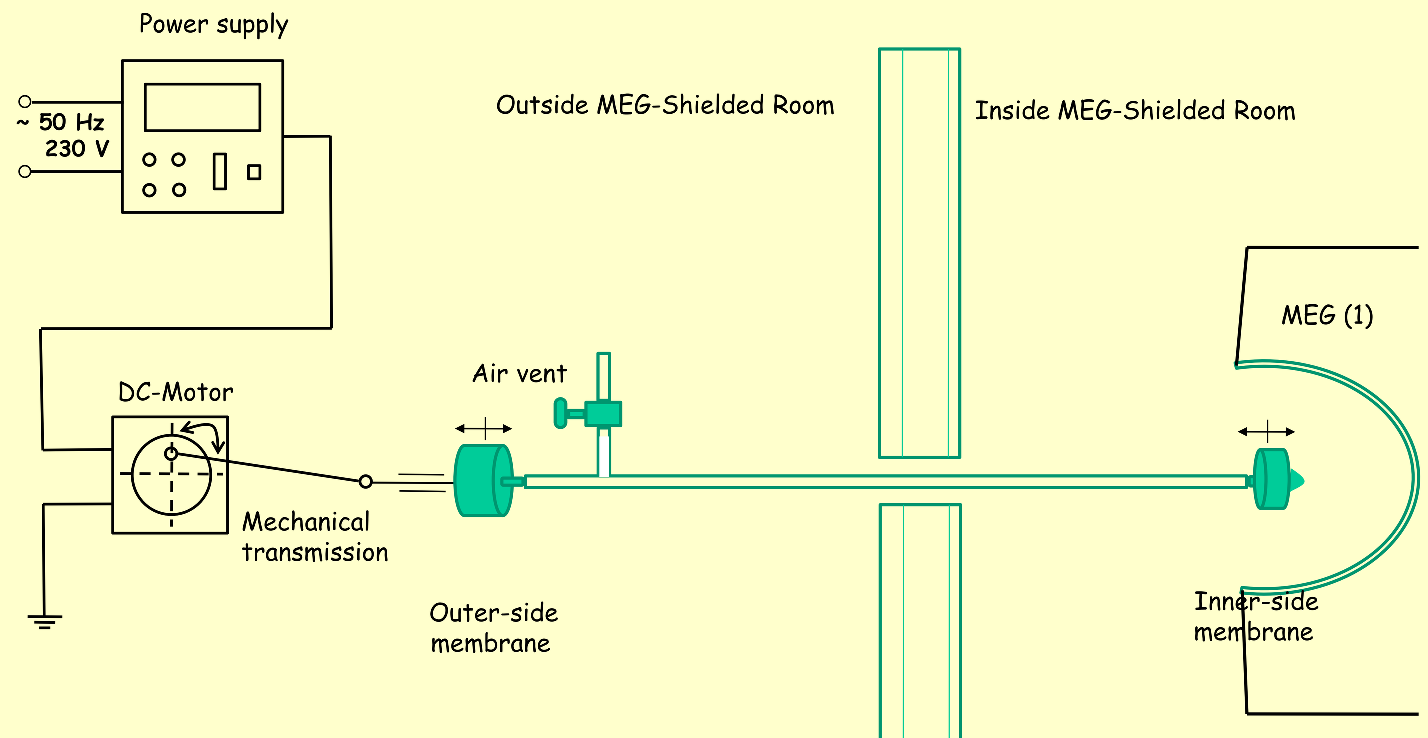
BRAIN TISSUE



CONCLUSIONS

- The new detection system opens new ways for the MEG-system to be used for biomedical research.
- It points to the design of vibrated SQUID detectors for macroscopic samples or objects contaminated with MNPs. Although there is still a long way up to the real practical application to human beings, research uses may be immediate.

EXPERIMENTAL SET-UP



The mechanical vibration produces an effective amplitude modulation of the magnetic field created by the nanoparticles that is detected by the MEG. The actuator part inside the MEG-shielded room, and is completely metal free. The pneumatic system is based on a 4-meter long flexible tube, with both ends closed by latex membranes. The outer side membrane is connected to an electric DC motor by a mechanical transmission which transforms rotation movement into linear motion. Nanoparticle samples are attached to the inner side membrane. In order to regulate the movement amplitude an air vent is implemented in parallel connection in the system. By increasing the valve opening, less pressure is transmitted between the membranes and the oscillation amplitude may be decreased to approximately 0.5 mm; by reducing it, the pressure transmitted increases, and the oscillation amplitude may reach around 2.3 mm. The frequency is regulated by using a voltage controlled power supply. Recordings were done using a 148 magnetometer whole-head system (Magnes 2500, 4D-Neuroimaging) housed in a shielded room.

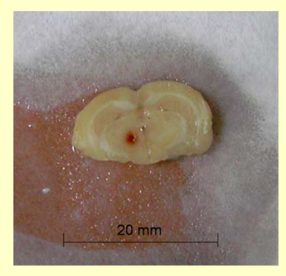
METHOD

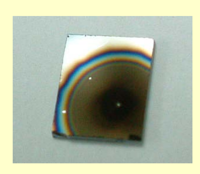
MNPs cluster with magnetic moment m, is vibrated at low frequency, Δl is the vibration amplitude of the nanoparticles cluster, r is the distance between the MNP and the MEG sensors, and ω is the pulsation of the mechanical vibration provided by the pneumatic system. The signal due to the sinusoidal component of the magnetic field is given by:

$$\Delta B = \frac{3\mu_0 m}{2\pi r^4}\Delta l \sin(\omega t)$$

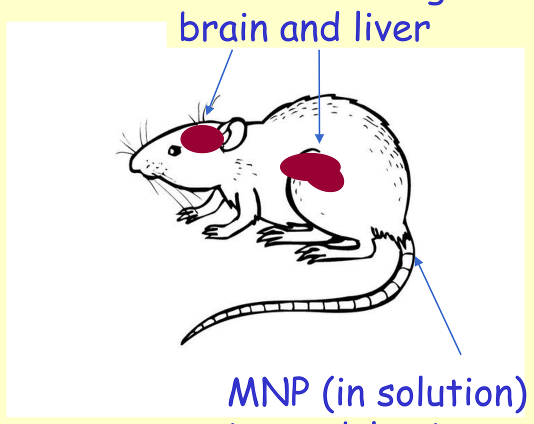
SAMPLES

Ni-MNP produced by sputtering in our laboratory



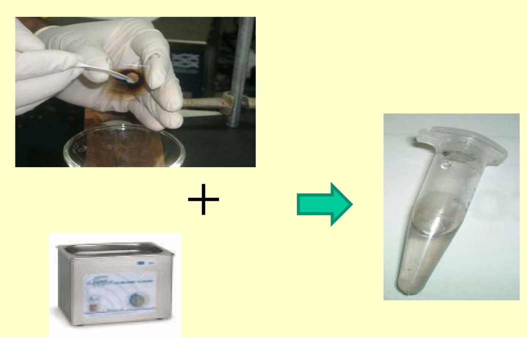


researched organs: brain and liver



MNP (in solution) injected in caudal veine

Material extraction



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